

The Computer Comprehension of Systematic Metaphor

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Abstract

This thesis presents a new approach to the interpretation of metaphors in natural language processing that is both demonstrably useful and computationally feasible. The remarkable ubiquity of metaphor in ordinary everyday English has been convincingly documented by George Lakoff and Mark Johnson in their seminal book *Metaphors We Live By*, where they show that there are a number of large scale metaphor schemas, which can explain the systematic borrowing of large numbers of words and phrases from one conceptual domain to describe a second domain, a phenomenon that can be termed 'systematic metaphor'. This metaphorical talk is so familiar that it passes largely unnoticed in conversation, but is sufficiently non-literal that it would cause severe problems for a computer system not equipped to deal with it.

The new computational approach to metaphor comprehension in this thesis is documented in three stages:

First, there is an outline of the theory of Descriptive Analogy – a new and general theory of metaphor which is capable of explaining many empirical observations; in particular, it covers *systematic* metaphor and its rôle in lexical semantics. Descriptive Analogy sees metaphor as the linguistic consequence of underlying *analogical* reasoning; furthermore this analogical reasoning is seen as fundamental to language production, underlying 'literal' as well as metaphorical utterances. Thus metaphor is liberated from its conventional classification as linguistically deviant and can be seen as entirely 'normal', a view that is well represented in the philosophical literature.

Next comes a presentation of DREP, a new, fully intensional, *analogical* semantic network formalism. DREP is a homogeneous formalism capable of representing both 'commonsense' knowledge and knowledge about systematic metaphors in precisely the same way. It is therefore particularly well suited to the requirements of Descriptive Analogy. This analogical representation is shown to offer a number of advantages over other, more conventional representation schemes.

Finally, there is a presentation and discussion of the MINT system – a computational implementation of the principles of Descriptive Analogy built around the DREP formalism. MINT generates literal paraphrases of a range of metaphorical input utterances, given knowledge only of the literal senses of words and a few simple analogies underlying systematic metaphors.

Preface

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....

This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration.

I hereby state that this dissertation is not substantially the same as any I have submitted for a degree, diploma or other qualification at any other university. Further, no part of this dissertation has already been or is being concurrently submitted for any such degree, diploma or other qualification.

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- B. Some Examples of Systematic Metaphors
- C. Some Examples of MINT's Processing

References

1. Introduction

Natural language understanding systems currently in existence can offer an impressive amount of grammatical coverage and vocabulary in specialized domains. Nevertheless, the input they can accept is still rather stilted and falls far short of true natural language. One area of natural language which currently lies outside the scope of most systems is figurative language and in particular, metaphor.

The remarkably pervasive use of metaphor in ordinary everyday English has been convincingly documented by George Lakoff and Mark Johnson in their seminal book *Metaphors We Live By* [Lakoff and Johnson 80]. They show that there are a number of large scale metaphor schemas, (they identify some fifty of these) which can explain the systematic borrowing of large numbers of words and phrases from one conceptual domain to describe a second domain, a phenomenon that can be termed 'systematic metaphor'. This metaphorical talk is so familiar that it passes unnoticed in human contexts, but is sufficiently non-literal that it would cause severe problems for a computer system not equipped to deal with it.

An example of a systematic metaphor is MORE IS UP,¹ where increasing and decreasing quantities are seen as rising and falling objects. Particular 'manifestations' of this systematic metaphor include

- (1) *Population is up / down / rising / falling / soaring / plummeting
High fidelity, low resolution, peak performance
A steep temperature gradient
Prices have fallen through the floor
Harry raised his bid
House prices have risen out of reach of the first time buyer.*

Many more examples of systematic metaphors are given in Appendix B.

This thesis describes the theory and practice of the MINT system – an original computer system capable of producing literal paraphrases of metaphorical input utterances, making use of commonsense knowledge and knowledge about *systematic* metaphors. Both kinds of knowledge are represented in the form of *analogies*.

1.1 A computational approach to metaphor

One's initial reaction to the idea of systematic metaphor might be that this is really 'dead' metaphor – are these not established literal word senses which can be looked up in dictionaries? This is a legitimate question to ask. There is an obvious intellectual challenge

¹ The names of these systematic metaphors are intended to be mnemonic, rather than accurate summaries.



in the long run to develop a way of dealing with novel metaphor in a computer system, but why bother with dead metaphor when all that is required is a sufficiently good dictionary? This section outlines the principal practical motivations for the computational study of systematic metaphor. Many of these reasons are explored in greater depth in subsequent chapters of this thesis.

Systematic metaphor is not dead metaphor!

The first point to make in defence of the study of systematic metaphor is that it is simply wrong to say that systematic metaphor is only manifested in 'dead' metaphors – it also includes many instances of novel metaphor, such as the following manifestations of TIME IS A MOVING OBJECT and ARGUMENT IS WAR (see Appendix B):²

- (2) *The hours hurtled past*
- (3) *The big guns in the audience were ready to shell Professor X's position.*

It is possible to envisage an extremely large lexicon in which a great many of these figurative word senses are listed, so obviating the need for special metaphorical processing in these cases, but it is unrealistic to expect this lexicon to be anything like complete. As a brief illustration, consider the example

- (4) *The weeks passed / rolled / trailed / tramped / marched / drifted / slid / flew / crept / crawled / sped / pelted / streaked / flashed / shot / tore / slipped / rushed / whizzed / hurtled / trickled by.*

All the choices of verb in this sentence are manifestations of TIME IS A MOVING OBJECT, the systematic metaphor in which words which 'normally'³ indicate physical movement are used to denote a sort of temporal 'movement'. Not one of these verbs is given an appropriate *literal* sense in *The Concise Oxford English Dictionary* (COED) [Oxford 76]. COED does give temporal *examples* for *fly* and *pass*, but the corresponding senses are defined as 'go', as if 'go' were literally applicable to time.⁴ COED also gives a temporal example for *trickle* explicitly labelled as figurative.

Longman Dictionary of Contemporary English (Longman's) [Longman 78] fares slightly better in that it offers temporal *examples* for its spatial senses of *pass*, *fly*, and *speed*, an admitted figurative example for *march*, an archaic, but literal, sense of 'to happen' for *pass* (as in 'it came to pass'), and senses '(of time) to go by' given for both *pass* and the

² These examples are due to Searle [Searle 79] and Cooper [Cooper 86] respectively.

³ This normality is discussed at length in subsequent chapters.

⁴ As a matter of fact, COED *does* list *go* as valid in a temporal as well as a spatial sense; however, this introduces an ambiguity in any definition given in terms of *go*, such as that for *pass*. This ambiguity means that when looking up the definition of *pass*, the dictionary user must disambiguate 'go' according to context. Thus it would seem that to store such dictionary definitions in a precompiled, *unambiguous* form for use by a computational system would entail multiplying the number of senses listed considerably.

collocation roll by.

So apart from a few scattered temporal examples, the overwhelming strategy employed on the part of the lexicographers is to give only a limited number of 'literal' senses and let the dictionary user infer figurative senses for himself. The computational approach in this thesis goes along with this compromise – figurative senses of words are inferred from literal senses as and when required.

Ubiquity of systematic metaphor

As Lakoff and Johnson pointed out, everyday English is riddled with systematic metaphor, both of the sort which can be anticipated in a dictionary and the sort that cannot. Such language is to be expected by a computer system when its input comes from an untrained user, such as a member of the general public, or from sources originally intended for a human readership, such as newspapers, books, newswires, and so on. All of these are very likely candidates for input to an applied natural language system.

For example, the following passages taken from the financial pages of newspapers and the radio⁵ exhibit manifestations of systematic metaphor that would be susceptible to such a treatment.⁶

- (5) *Mr. Steel was brought into Guinness two years ago ... to mastermind Guinness's expansion in the drinks trade.*
- (6) *As oil prices fell, platinum led the general retreat of precious metals.*
- (7) *The City viewed the move as a grave blow to a bank whose morale was already at a low ebb, following the collapse of merger talks with Union Bank of Switzerland.*
- (8) *Government stocks fell sharply yesterday, hit by the weakness of the US bond market and fears of higher interest rates. The pound lost some of its earlier strength as the dollar steadied.*
- (9) *The education system has been stretched to breaking point.*

Realism

A second point to make is that the aim of tackling *general* metaphor without any appeal to prior knowledge of suitable analogies (for it will be seen that analogies hold the key to the interpretation of metaphors) is extremely ambitious – research along these lines, such as in [Indurkha 85, 86, 87], suggests that unrealistically large amounts of world knowledge, appreciation of context, and sheer processing power would be required. Furthermore the analogies behind metaphors, especially manifestations of systematic metaphor often appear

⁵ *The Times, The Sunday Times, and Radio 4.*

⁶ These examples display figurative language other than metaphor, particularly metonymy [see Glossary]. Personification can be seen as a particularly common form of systematic metaphor.

quite arbitrary: the analogy between, say, a person's emotionality and an object's temperature is hardly obvious, no more so than an alternative analogy with, for example, colour, and yet this analogy underlies the systematic metaphor EMOTIONALITY IS TEMPERATURE discussed in Chapter 2. It would therefore be asking a great deal of a computational theory to come up with such an analogy from first principles.

It can be hoped that more rapid progress can be achieved by concentrating on *systematic* metaphor, since when interpreting such metaphors it is not necessary to start completely from scratch. Nevertheless, the fact that systematic metaphor does involve metaphorical processes means that its study can be expected to yield valuable experience when it comes to tackling more ambitious metaphors.

Reducing the size of the lexicon

Exploiting systematic metaphor means that the size of a system's lexicon can be reduced. This would be achieved by removing word senses that can be seen to be accounted for by systematic metaphor, leaving 'core' literal senses that can be used in conjunction with known analogies to reconstruct the required senses during processing. This is of course a trade-off between data space and processing complexity, and in practice, the right compromise would need to be reached; but in the light of previous comments, the processing machinery would need to be there in any case to deal with unanticipated cases of systematic metaphor.

There is, however, a danger associated with the removal of these metaphorical senses: many of them are sufficiently well established to have acquired an idiomatic meaning which cannot be recovered by treating them as instances of systematic metaphor. This would seem to argue that such senses should be left in the lexicon; if there are too many of them, however, it would be impossible to choose in advance which ones would be required. Since their idiomatic meaning is unlikely to be *very* far removed from the meaning which can be given them as instances of systematic metaphor, omitting idiomatic senses would mean treating them imperfectly, but nevertheless usefully. This attitude would allow a sort of graceful degradation in performance of the system as a whole at the limits of its vocabulary.

Technical word senses

It has been pointed out that in a transportable natural language front end for, say, a database query system or an expert system, there can be a large investment in word definitions and world knowledge, which is likely to be rendered misleading or useless when ordinary words are used in technical, domain-dependent senses [Boguraev *et al.* 88], [Copestake and Sparck

Jones 89]. In this case, there is a good possibility that these technical senses can usefully be considered as metaphorical senses of the common, domain-independent words; after all, the technical words are unlikely to have been chosen at random, but rather because of some perceived similarity in meaning. If the system treats this basic relationship between the common and technical word senses as a systematic metaphor, then it is in a position to process extensions of that metaphor making use of its general, domain-independent knowledge. An example of this in operation would be a systematic metaphor which sees the functionality of a computer program as its metaphorical health. Thus a process, an editor say, can be spoken of as being unwell, ill, dead, dying, recovering, it can be killed or revived, or cured of its bugs. By giving the system knowledge of one 'core' analogy, it gains the wherewithal to handle all these technical word senses and still more which have not been anticipated in advance.

In summary, then, it is essential in the long run that computational linguistics develops a way of dealing with metaphorical language. To tackle novel metaphor without appeal to knowledge of underlying analogies is rather too ambitious given the state of the art, but systematic metaphor seems much more feasible in the short term, offers real practical benefits, and can be expected to offer valuable insights into the processing of more difficult metaphors.

These motivations have been born out in the MINT system described here. In MINT, systematic metaphors are encoded very concisely as analogies in the system's knowledge base, and a single such analogy enables MINT to interpret many different manifestations of the corresponding systematic metaphor, given only *literal* meanings for the words involved. For example, MORE IS UP is represented as a very simple analogy, but this *single* analogy enables MINT to interpret many different words metaphorically, words such as 'rising', 'falling', 'soaring', 'plummeting', 'high', 'low', 'higher', and 'lower'.

1.2 Aims and Methodology

The overall aim of this work is to develop a computational system which is capable of 'understanding' instances of systematic metaphor in a way that is both computationally useful and feasible. This understanding of metaphor is not intended to cover the arresting sort of metaphor such as one might find in poetry or rhetoric, rather it is aimed at the more prosaic, everyday sort of metaphor which is ubiquitous in conversation, journals, commercial documents, and so on. As argued above, this sort of metaphor is at once more tractable and more obviously useful in applications envisaged for natural language systems in the near future.

The scope of systematic metaphor is still very wide in terms of the complexity of linguistic manifestations that can arise. In order to limit the requirements of the computational system to a realistic level, attention is focused principally on those manifestations in which a single word or collocation is used metaphorically; that is, where individual words are given metaphorical senses. This focusing on small scale lexical semantics is, however, to be done in a way that would readily admit extension to larger semantic units.

A theory of metaphor

This major goal can be broken down into various subgoals as follows. The first step is to develop a computationally useful theory of metaphor starting from existing theories from philosophy, linguistics, and computational linguistics. Such a theory should be sufficiently detailed and advanced that it can be used as a basis for a computational system capable of demonstrating some of the potential benefits of handling systematic metaphor.

The particular existing philosophical and linguistic theories to be expanded upon are those of George Lakoff and Mark Johnson, who give an extensive account of systematic metaphor as a psychological phenomenon in [Lakoff and Johnson 80], and Max Black, whose 'interaction' theory of metaphor [Black 62, 79] seems to offer the most promising framework on which to build a computational theory. The interaction theory as it stands lacks an account of systematic metaphor and it also lacks any detailed mechanism for interpreting metaphors – it is an aim of this work to incorporate both of these.

An analogical knowledge representation

The second step is to develop a knowledge representation which is well suited to representing systematic metaphors and supporting the analogical reasoning required by the theory. At the same time, it seems desirable, from the philosophical and linguistic evidence,⁷ to accommodate 'literal' knowledge in a way that is not greatly different from 'metaphorical' knowledge. As the representation is only intended to support an experimental demonstration system, it is preferable to keep it simple, rather than to try to cater for too many representational issues which are not directly concerned with metaphorical processing – the representation does not have to be, say, logically adequate: the extra burden of dealing with negation and quantification would only be a hindrance to the investigation of metaphor.

It seems preferable to start with a new representation, rather than try to adapt an old one, as metaphorical reasoning appears to be qualitatively different from the sort of reasoning

⁷ Detailed in Chapter 2.

supported by existing general knowledge representations, and there is a considerable danger that an attempt to force metaphorical knowledge into an old mould would tend to distort the processes at work beyond useful recognition. By devising a new and simple representation, in which metaphorical knowledge could be accommodated naturally, there is a substantially better chance of getting a clear view of what was happening and of being able to give the system a semantics which motivates processing.

An experimental system

The third and final step is to incorporate the knowledge representation into a larger system which actually performs the processing of metaphors. The system is to be capable of accepting input which might contain manifestations of systematic metaphor and produce from this input a literal paraphrase acceptable to a conventional, though hypothetical, application. The task of this system is described more fully later in this chapter.

General methodological aims

A general methodological aim of the work is to keep it as simple as possible as far as this is consistent with the aims outlined above. This simplicity has the twin advantages of making the task more tractable and of making it possible to see more of the wood and less of the trees. This is of major benefit when developing a theory in a relatively novel field – MINT is not intended to form the basis of a large natural language system, rather it is to be a test-bed system, a means to evaluate the theory of systematic metaphor by showing up any defects or inadequacies, thus providing feedback in a development cycle.

This simplicity also means that it should be possible to concentrate on developing the theoretical issues without worrying about whether the system, and in particular the representation, would be adequate to deal with, say, anaphor resolution, negation, or quantification. The result should be a system that embodies the essence of the theory concerned, so while the system itself might not be easily extended to perform a greater range of NLP tasks, the lessons learned should be easier to see and to apply in other, more complex, systems.

It should be pointed out that it is *not* an aim of this work to produce a psychological model of metaphor comprehension. The emphasis is very much on producing a computationally useful theory, though of course this does not mean to say that psychologically interesting ideas will not turn up, it is left to the reader to identify such ideas.

1.3 The research context

There has been a great deal of work on metaphor in philosophy and linguistics, but rather little in computational linguistics until relatively recently. The lack of computational studies can perhaps be explained as due to an early attitude that metaphor is a relatively uncommon phenomenon, often regarded as deviant language, and so low on the list of priorities. There have, however, been a few attempts to analyze simple metaphors of the form 'A is [like] B' based on selective transfer of properties, for example [Winston 78], [Weiner 84].

More recently, however, and especially since the publication of *Metaphors We Live By* [Lakoff and Johnson 80], there has been a growing realization that metaphor is in fact extremely common in the sort of language that computational linguists are interested in dealing with. Consequently there have been a number of attempts to incorporate some metaphor handling capacity into existing systems, but without focusing on the theoretical issues. Isolated examples of metaphor are dealt with in [Wilks 77, 78], [Fass and Wilks 83], and simple treatments of systematic metaphor are given in [Hobbs 77, 79, 81], [Jacobs 87, 88], [Martin 87, 88].

This current work, however, is best seen as following on from the more theoretical studies of metaphor made by Carbonell [Carbonell 80, 82], [Carbonell and Minton 85] and Indurkha [Indurkha 85, 86, 87]; these authors see *analogical reasoning* at the root of metaphorical interpretation.

Lexical semantics

This work may also be seen as part of a growing trend in lexical semantics to identify regularities in the way words form distinct but related senses, and to use this knowledge to reduce the superabundance of word senses that need to be listed in the lexicon of a computer system. The observation behind this is that the harder one looks at the way a particular word is used, the more senses it appears to have. The usual reaction to this in computational linguistics is to list all these senses separately, but this consumes a great deal of space and requires a great deal of foresight. By exploiting regularities, though, it might well prove possible and beneficial to generate some of these word senses automatically (either 'on the fly' at run time or in advance at 'compile' time). This could be achieved by adding sufficiently to the semantic information in lexical entries and having a richer notion of compositionality, one that reflects the observed regularities in word sense derivation.

The research presented here aims to exploit *metaphorical* regularities, James Pustejovsky has investigated how to exploit *metonymical* regularities [Pustejovsky 89], and Beth Levin has sought to exploit *syntactic* regularities [Katz and Levin 88].

1.3.1 Related work

This research is aimed towards the development of a small demonstration system. A larger system would require greater depth in several areas, so this work can be seen as complementary to work in several closely related fields:

Analogical reasoning

Analogical reasoning has been studied intensively by many researchers, some, as mentioned above, in relation to metaphor, and many in the context of machine learning, see [Hall 89] for a survey. There have also been computational implementations of psychological models of analogical reasoning [Gentner 87, 89], [Falkenhainer *et al.* 86, 87, 89], [Holyoak and Thagard 89]. The analogical reasoning capabilities of the MINT system developed here are relatively simple, as more complex reasoning is not required for the task in hand. Nevertheless, a more comprehensive system that can handle more difficult metaphors would probably require a greater ability in this area.

Metonymy

Metonymy [see Glossary] is a figure of speech closely related to metaphor, and indeed sometimes reckoned to be a subclass of metaphor; Lakoff and Johnson found instances of systematic metonymy analogous to systematic metaphor [Lakoff and Johnson 80]. Certainly the two figures often occur together and ought to be handled together in a more realistic system. Computational accounts of metonymy are given in [Fass 85, 86, 88a, 88b], [Pustejovsky and Anick 88], [Pustejovsky 89].

Naïve semantics

The interpretation of metaphor depends crucially on a degree of commonsense knowledge, Lakoff and Johnson observed that this knowledge is very often of a physical nature, the sort of knowledge that has been dubbed 'naïve physics' in the computational literature [Hayes 85], [Hobbs *et al.* 86], [Hobbs 87]. Consequently, the results of research into naïve physics would be highly relevant to a fuller implementation of this research. A rather more general semantic investigation, that of 'naïve semantics', based on psychological evidence has been given by Kathleen Dahlgren [Dahlgren *et al.* 89]. This concentrates on non-physical semantic knowledge of the sort that would be appropriate for use with the system outlined here.

1.4 The theory of descriptonal analogy

The theory of descriptonal analogy developed in chapters 3 and 4 sees the linguistic phenomenon of metaphor as evidence of analogical reasoning – all metaphors are seen as being dependent on some 'underlying' analogy and a metaphor (that is, an actual utterance or piece of text) can be interpreted by reconstructing this analogy and reasoning with it.

In a simple metaphor, according to the theory, one thing (the 'target') is 'viewed' analogically as another (the 'source'). For example, in the metaphor

(10) *John is a pig*

John is the target and the pig is the source. In more complex metaphors, more than one source and target are involved.

This view is summed up in the Principle of Descriptonal Analogy:

A metaphor is the linguistic manifestation of an underlying analogy between its sources and targets. Moreover, given an analogy, any description of its sources can be applied metaphorically to the corresponding targets.

For example, in (10), "is a pig" is a description of the pig in the analogy, and this description is applied metaphorically to John.

The phenomenon of 'extended metaphor' is then seen to occur when the analogy underlying one metaphor is re-used and elaborated in subsequent metaphors in the same discourse or text. The phenomenon of 'systematic metaphor' is seen to rely on a common analogy underlying many individual metaphors which may come from entirely separate texts. Each such pattern of metaphors is called 'a systematic metaphor', and these are given mnemonic labels conventionally written in capitals. An example already seen is MORE IS UP and several more examples are given in Appendix B.

A metaphor (i.e., an utterance or piece of text) that can be seen to come under the umbrella of one of these systematic metaphors is called a 'manifestation' of that systematic metaphor.⁸ The common analogy underlying all manifestations of a particular systematic metaphor is called its 'core analogy'.

The theory of descriptonal analogy offers a number of significant advantages over other theories, principal among which (in the context of this work) is that it talks of *descriptions* of the source being inherited by the target, and not just *properties*. Such descriptions may themselves be metaphorical, and so metaphorical interpretation becomes a *recursive* procedure. This recursiveness is seen to be of central importance to the operation of systematic metaphor.

⁸ A metaphor can be a manifestation of more than one systematic metaphor.

Literalness

The notion of literalness proves to be very hard to define, for the simple reason that it seems impossible to provide an objective way of distinguishing between 'literal' and 'metaphorical' utterances. This difficulty spills over into the classification of metaphor, where authors have frequently tried to distinguish between 'novel metaphors' and 'dead metaphors'. Such authors have claimed that dead metaphors should be regarded as literal, but there is evidence to show that these metaphors continue to display much of their metaphorical nature long after death, and in particular can often be seen to be manifestations of systematic metaphors.

The theory of descriptonal analogy explains this observation by asserting that literalness is a relative notion, and so the distinction between 'novel' and 'dead' metaphors is only one of degree. Indeed, the processing of most 'literal' utterances is seen as using precisely the same analogical mechanisms as the processing of metaphors, literal utterances are seen as 'metaphors' whose sources are 'definitive entities'. This is in line with the so-called 'primacy' theory of metaphor outlined in chapter 2.

1.5 A brief outline of DREP

DREP is an original homogeneous semantic network formalism in which nodes are atomic but links are structured, linking more than two nodes at a time. In line with the theory of descriptonal analogy, nodes correspond to intensional entities, and each of the structured links ('d-links') is seen as representing an analogy. *All* knowledge in the network is represented either in this way, or by direct links from collections of nodes into the lexicon – there is no equivalent of the is-a link.

The analogical nature of DREP means that it is possible to avoid completely the idea of 'instantiation' and also rigid notions of frame and domain. This gives DREP significant advantages over rival representations in addition to its particular suitability for handling metaphor.

The semantics given to DREP is a fully intensional semantics based on Castañeda's Guise-Consubstantiation theory [Castañeda 77].

1.6 A brief outline of the MINT system

Figure 1 shows how MINT fits into a full scale natural language processing system. It can be seen to be a sort of preprocessing component that accepts input from a naïve parser, input which retains the metaphoricality of the English, and generates from it a literal

paraphrase, which is then passed to an application program. 'Literal' in this context means that the paraphrase is directly 'meaningful' to the application program, i.e., all words (or more accurately, predicates) are used in their 'literal' senses.

This literal paraphrase is in reality a loose collection of logical forms each of which lends a partial meaning to the input utterance. The paraphrase as a whole may only represent a partial account of the input, depending on how successful MINT is in identifying the metaphors involved, but this partial interpretation is presumed to be (much) better than nothing at all.

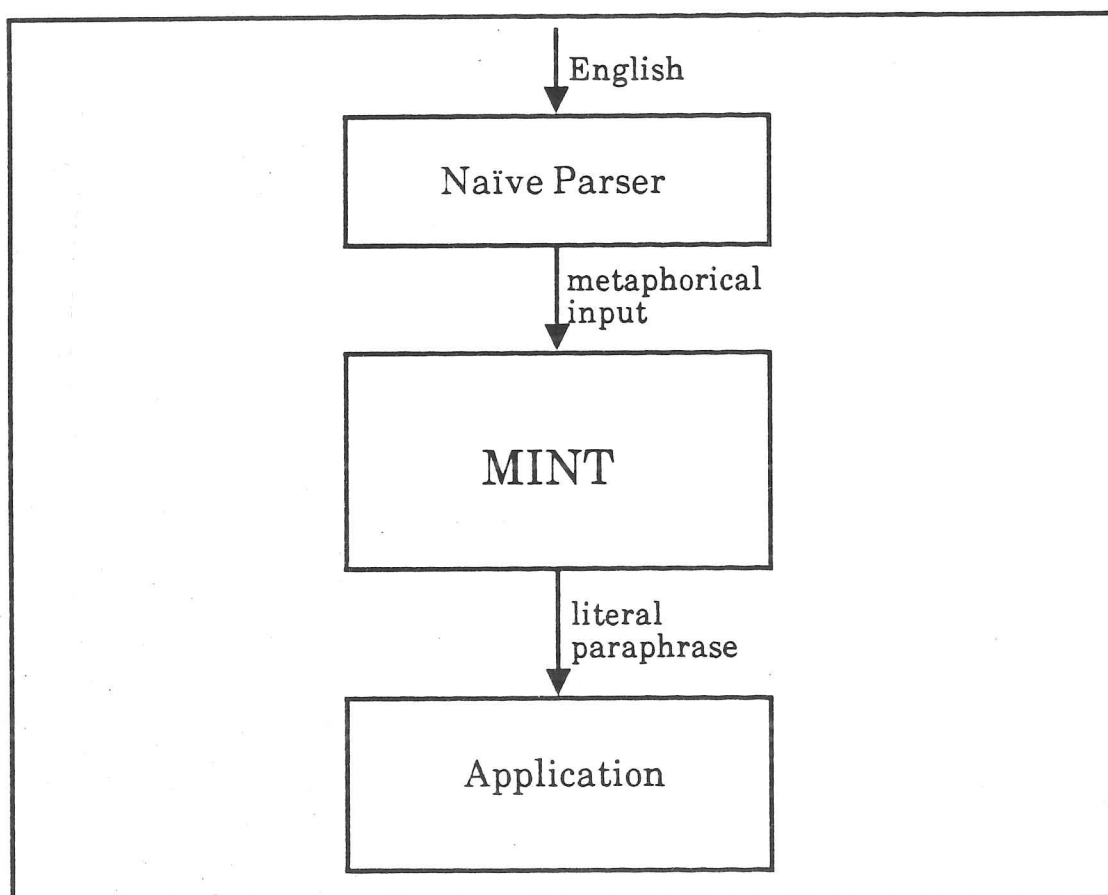


Figure 1: The MINT system in context

A simple example of the sort of utterance that MINT processes is

(11) *The price of gold is soaring*

which is paraphrased as⁹

(12) *The price of gold is increasing rapidly to a great level.*

⁹ Actually, the input and output of MINT is in logical form, not English.

Here, 'soaring' is seen as a word that means 'rapid upwards physical movement to a great height', and so it is not considered literally applicable to prices. MINT achieves its paraphrases by appealing to its knowledge of the literal definitions of the words involved and its knowledge of the MORE IS UP systematic metaphor. It is a significant feature of the DREP representation that both types of knowledge can be represented in a uniform way.

A rather more complex example processed by MINT, a manifestation of the so-called 'Conduit' metaphor [Reddy 79], is

(13) *John got his argument across to Bill,*

where the literal sense of 'get across' is taken to involve physical movement. This example is paraphrased, roughly, as

(14) *John communicated his argument to Bill.*

Appendix C shows MINT successfully producing literal paraphrases of about thirty examples involving systematic metaphor.

1.7 Thesis organization

Chapter 2 is a brief survey of the occurrence of metaphor in English, outlining some of the linguistic and philosophical observations to be made and summarizing the major linguistic theories of metaphor. Also in chapter 2 is a survey of previous computational approaches to the interpretation of metaphor. This chapter gives a frame of reference for the rest of the thesis, defines and explains much of the terminology, outlines many observations which are to be explained by the theory of descriptonal analogy, and gives the linguistic and philosophical starting points for the development of that theory.

Chapters 3 and 4 pick up on the background of chapter 2 and develop the theory of descriptonal analogy to a point where it is suitable for implementation in a computer system.

Chapters 5 and 6 describe in detail DREP, the representation formalism at the heart of the implementation and how it is used in MINT, the overall system.

Chapter 7 concludes the thesis with a discussion of the theory of descriptonal analogy and its implementation, how they perform and how they relate back to the initial observations on metaphor made in chapter 2. There is further discussion on how the theory and system might be extended and improved in further research.

2. The Phenomenon of Metaphor

There has been a great deal written about metaphor; Shibles's annotated bibliography [Shibles 71] contains over 4000 titles, van Noppen's [Noppen 85] lists a similar number of works published between 1970 and 1985. This chapter is not intended to be a comprehensive survey of either the history or the theory of metaphor, rather it is to be a short tour around the subject area, showing some of the background to this thesis, identifying some of the terminology used, and providing the motivating observations behind the development of the computational theory of metaphor presented in chapters 3 and 4. These observations are reconsidered when assessing the results of this research in chapter 7.

Overview

The discussion in this chapter divides into five main parts. In 2.1 the general occurrence of metaphor in English is investigated to get an idea of just what a computational (or indeed any) theory of metaphor should seek to cover. In 2.2 the notion of *systematic* metaphor, which is the central concern of this thesis, is explored to see how it is manifested and how it relates to metaphor in general. In 2.3 the issue of why metaphor is used at all is tackled, a question that leads to a number of important observations. In 2.4 there is an appraisal of some existing theories of metaphor, which gives a foundation for the theory of descriptonal analogy to be developed in the next two chapters. Finally, in 2.5 there is a brief look at the major computational accounts of metaphor that have been developed to date.

2.1 What is Metaphor?

A successful definition of metaphor has proved elusive over the years since Aristotle's characterization of it as "giving a thing a name that belongs to something else". Authors have been divided about just which phenomena to include under the umbrella of metaphor, but there does seem to be a general acceptance that metaphor finds its place among the so-called 'tropes' or 'figures of speech'. The tropes of particular interest in this work are metaphor, simile, metonymy, idiom, irony, hyperbole, and litotes [see Glossary].

An initial, but very loose characterization of metaphor is that it involves describing something as if it were something else – using words or phrases which do not apply literally. For example, in Shakespeare's *Richard II* England is described as

- (15) *This nurse, this teeming womb of royal kings.*¹

The 'something' being described need not be a simple object, but could be an event, an activity, or just about anything. The following examples taken from the literature describe a wide variety of these 'somethings':

- (16) *Religion is the opium of the people*
(17) *The government is sailing close to the wind*
(18) *Mrs. Gandhi steamed ahead*
(19) *The US/Russian arms negotiations are a high stakes poker game.*

This initial characterization of metaphor is rather too vague to be of much use in the computational context, and in particular, the notion of literalness needs pinning down. The next few pages will try to give a better indication of what is involved in metaphor by exploring its various manifestations.

Some terminology

But first, it will be useful to define a few terms. The term 'c-entity' ('c' for 'conversational') will be used to mean 'something that can be described'. C-entities already seen in the examples above include England, religion, the sailing of a ship close to the wind, and the government's pursuit of its policies. In particular it should be noted that a c-entity's identity is independent of the words used to describe it, it is a 'mental' object. In the conception of metaphor presented above, two c-entities are crucially involved: one c-entity, the 'target', is seen or described as if it were a second c-entity, the 'source'. Thus religion is the target of (16), and the opium of the people is its source.

A c-entity may be said to belong to a 'conceptual domain' – thus the government's pursuit of its policies belongs to the domain of government, sailing close to the wind belongs to the domain of sailing. It should be emphasized that the idea of a conceptual domain is intended only as a very informal notion, as in general such domains are extremely difficult to delineate, nevertheless the notion of a domain is one that will prove useful in discussing the issues involved in metaphor. The conceptual domains of the source and target of a metaphor are termed the 'source domain' and the 'target domain' respectively.

Using this terminology, a metaphor involves drawing descriptive terms from its source domain and applying them to its target.²

¹ Shakespeare's *Richard II*, Act II, Scene 2

² The terminology is unfortunately not at all standard in the literature. Source and target are sometimes called 'frame' and 'focus', or 'secondary' and 'primary' subjects, or 'vehicle' and 'topic', or 'referent' and 'subject'. The choice of the terms 'source' and 'target' here is intended to reflect the directionality of the transfer of descriptive terms in metaphor.

2.1.1 Classes of metaphor

Metaphor comes in a variety of forms. George Miller [Miller 79] provides a useful classification by dividing metaphor into nominal, predicative, and sentential metaphors.

Nominal metaphor

The simplest of these is the 'nominal metaphor', where the target is expressed or described by a metaphorical noun phrase, as in (16) and (19), and (20) – (22):

- (20) *Man is a wolf*
- (21) *Inflation is a disease*
- (22) *John married a gem.*

Nominal metaphor can also be said to include metaphorical definite reference, as, for example, in (23):

- (23) *The disease has lasted a long time* [meaning inflation].

Predicative metaphor

Miller's second class of metaphor is 'predicative metaphor', where a predicate, taken to be some verb, verb phrase, or adjective, is applied metaphorically to a target. This category covers (17) and (18), as well as examples such as

- (24) *Mountain climbing is murderous.*

Sentential metaphor

Miller's third and final class of metaphor is the 'sentential metaphor', which describes "an otherwise unobjectionable sentence in an incongruous context". Examples of sentential metaphor are

- (25) *John has lost his marbles*
- (26) *Mrs. Thatcher bulldozed her way through the dissenting ranks*
- (27) *This disease is crippling us* [meaning inflation].

Proverbs also tend to fit into this category:

- (28) *A stitch in time saves nine*
- (29) *You can't make an omelet without breaking eggs.*

Sentential metaphor, and also the earlier observation about definite reference, shows that a particular sentence cannot in general be judged as metaphorical or literal without consideration of its context. Thus metaphor should not be regarded *only* as a problem in

semantics, but also as a problem in pragmatics – we should be talking about metaphorical *utterances*, rather than metaphorical *sentences*.³ The pragmatic issues involved in metaphor are investigated further later in this chapter.

Miller's three classes of metaphor can all be seen to fit in with the loose characterization of metaphor given earlier: all three of them describe their target as if it were something else.⁴

This classification considers only metaphors occurring within a single sentence, but it is possible to see metaphor operating at a higher level:

Extended metaphor

There is another commonality between Miller's classes, and it is this: all three categories of metaphor seem to express a kind of similarity or *analogy* between their targets and their sources. Another way of saying that a target is *described* as though it were the source is to say that the target is *seen*, or *viewed* as the source. (This observation of similarity is what relates metaphor so strongly to simile, and what distinguishes metaphor from metonymy, more of which later).

The term 'extended metaphor' is used for a series of individual metaphors in which such a similarity or analogy is re-used and elaborated over time. A good example of this sees England as a garden:

- (30) ... *our sea wallèd garden, the whole land,*
Is full of weeds, her fairest flowers choked up,
Her fruit trees all unpruned, her hedges ruined,
Her knots disordered and her wholesome herbs
*Swarming with caterpillars?*⁵

Indeed, whole texts can be classed as extended metaphors. Parables would be an example of this, as would allegories, such as John Bunyan's *The Pilgrim's Progress* and George Orwell's *Animal Farm*.

These important observations, that analogy can be seen to underlie metaphor and that metaphor can be extended, are central to the computational approach to metaphor developed in this thesis.

³ I follow convention in using the terms 'speaker', 'hearer', and 'utterance' to include 'writer', 'reader', and 'text'.

⁴ Note that it is not necessary for the target of a metaphor to be referred to explicitly by means of a noun phrase, in predicative and sentential metaphors especially, the source is often an event or action being described.

⁵ A gardener's speech in Shakespeare's *Richard II*, Act III, Scene 4

2.1.2 Dead metaphor

Many authors argue that the central quality of metaphor is its novelty, its life, its colour, its ability to conjure up images in the hearer's mind. After a while, a metaphor becomes tired and dull, it loses its novelty and simply fades into ordinary language. To such authors, this corpse of a metaphor no longer merits the title 'metaphor' at all, its interpretation rests squarely in the realms of the literal, it becomes just another word sense or idiom, it becomes a 'dead metaphor'. Such a fate has befallen examples such as

- (31) *Tom is a pig*
- (32) *The crime rate is rising*
- (33) *The jury must sift the evidence*
- (34) *They buried the hatchet.*

Dead metaphors are usually contrasted with 'novel metaphors', which are supposed to be new to the hearer, requiring full metaphorical processing to interpret. The distinction between dead and novel metaphor is, however, not at all easy to define, as will be seen, but the terminology is useful in more informal discussion.

This supposed dichotomy between dead and novel metaphor reveals a key question for the computational linguist: is there a qualitative difference between processing dead metaphorical utterances and novel metaphorical utterances?

Literalness

It is not at all clear when a metaphor dies just when the transition between metaphorical and literal occurs. Where, for example, asks Levinson, does metaphorical processing take over from literal processing in the following sequence?⁶

- (35) *John came hurriedly down the stairs*
John ran down the stairs
John rushed down the stairs
John hustled down the stairs
John shot down the stairs
John whistled down the stairs.

Is it the case that there is a smooth transition between two distinct types of processing, or is it the same machinery in all cases, but with the more 'literal' pathways being better oiled?

The simplest test of literalness, and one that has been assumed by many authors, is one of whether a given word sense, or idiom, can be found in a dictionary – if a word sense has made it into a dictionary, then it should be counted as part of 'literal' language. This definition, however, presents an obvious problem: whose dictionary should be used, and is it

⁶ [Levinson 83], p. 150

the same for all speakers and hearers? The equally obvious answer is that there is no standard dictionary, and so a better notion of literalness must be found. The search for such an improved notion is a theme of this chapter.

Homonymy and polysemy

In the search for a better notion of literalness, it is revealing to take a closer look at dictionary entries, and in particular the notions of 'homonymy' and 'polysemy'.

For a given word-form (a simple combination of letters), there can be a number of different word senses defined in a dictionary. These senses are first divided into 'homonyms', which are unrelated in meaning, such as **bank**₁ = 'side of a river' and **bank**₂ = 'financial institution'. Homonyms are then subdivided into 'polysemes', which have separate, but related, meanings. For example **mouth**₁₍₁₎ = 'facial orifice' and **mouth**₁₍₂₎ = 'opening of bottle, cave, etc.' are polysemes.

The notion of relatedness of meaning is unfortunately rather vague, and so it is difficult to draw a precise line between homonymy and polysemy. There are two plausible lines to take – the diachronic approach (based on etymology) and the synchronic approach (based on observations of the current usage of words). There is often, however, a conflict between the two approaches, and some sort of compromise has to be reached.⁷

Another problem for the lexicographer is the question of how far to split a homonym into polysemes – should there, for instance, be separate polysemes for 'mouth of a cave' and 'mouth of a bottle', or should they be lumped under a single more general polyseme?

Dead metaphors can be seen to give rise to polysemes of their 'parent' word senses, relatedness of meaning being assured by the similarity which the metaphor expressed.⁸ So, for example, **attack**₁₍₁₎ = 'military assault' [parent sense] and **attack**₁₍₂₎ = 'disputing of argument', are polysemes, as are **rise**₁₍₁₎ = 'increase in height' [parent sense] and **rise**₁₍₂₎ = 'increase of a quantity'. In this way, a homonym can be seen to be typically divided into a parent polyseme and a number of derivative 'metaphorical' polysemes,⁹ although this distinction is not usually made in dictionaries. This idea of a 'parent sense' will be made more formal later and used as the basis of a computationally useful idea of literalness.

⁷ See, for example, [Lyons 77] section 13.4.

⁸ The identification of parent senses is not always uncontroversial.

⁹ Derivative polysemes also arise through other tropes, such as metonymy and synecdoche. For instance, in [Longman 78], **sail** is given the following polysemous senses: 1 a piece of strong cloth fixed on a ship to catch wind [parent]; 2 a boat driven by these [synecdoche] 3 a short trip in a boat with these [metonymy] 4 distance at sea measured by the time a ship would take to travel it [metonymy] 5 any of the broad wind-catching blades of a windmill [metaphor].

A detailed analysis of polysemous senses of **run** arising from metaphor, generalization and metonymy is given in [Bartsch 82].

'Mere polysemy'

It has been seen how lexicographers go to much trouble to distinguish homonyms and polysemes, but there does not seem to be any *prima facie* computational advantage in the distinction – polysemes are just word senses to be disambiguated in much the same way as homonyms. Indeed, the usual approach of computational linguistics has been to treat all these word senses as homonyms, independent words which just happen to have the same spelling. We might term this egalitarian attitude to word senses the 'mere polysemy' approach. It turns out, however, that there are definite advantages to be had from recognizing the distinction between homonymy and polysemy, and these advantages stem from the observation that, with a little prodding, dead metaphors show distinct signs of life, and with a wider perspective, their metaphorical nature can be seen to be hard at work, as we shall see in the next section.¹⁰

2.2 Systematic metaphor

On a sentential level, testing with the word 'literally' and the phenomenon of 'mixed metaphor' show that hearers are mindful of a dead metaphor's origins, and so a full transition to 'literal' meaning cannot have taken place. Consider our earlier examples of dead metaphor with the word 'literally' inserted:

- (36) ? *Tom literally is a pig*
- (37) ? *The crime rate literally is rising*
- (38) ? *The jury must literally sift the evidence*
- (39) ? *They literally buried the hatchet.*

Fowler's example of mixed metaphor, or as he would call it, 'tasteless word choice':

- (40) ? *All the evidence must first be sifted with acid tests*

shows that 'sift' cannot be regarded as a literal substitute for 'examine', neither can 'acid tests' be a literal substitute for 'definitive tests' – the interaction of the two incompatible 'dead' metaphors reveals their metaphorical roots. This phenomenon can even be seen to occur with words whose metaphoricality can only be traced in their etymological origins. Similarly, dead metaphors like to be used in metaphorically suitable collocations: one imposes a burden, applies a stimulus, jumps a hurdle, lifts a barrier.¹¹

¹⁰ There are similarly good reasons for recognizing polysemes as arising from other tropes, such as metonymy.

¹¹ see [Fowler 65] entry for metaphor.

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¹¹ see [Fowler 65] entry for metaphor.

Systematic metaphor

A more impressive show of the residual metaphorical nature of 'dead' metaphors becomes apparent when one no longer considers metaphors in isolation, but instead looks for larger patterns of metaphorical language. Time and time again, words can be seen to be imported wholesale from one domain and applied systematically in another [Lakoff and Johnson 80]. The phenomenon, which is here termed 'systematic metaphor' involves a single 'core analogy' underlying a whole host of individual metaphors, live and dead. For example,

- (41) MORE IS UP:¹²
Population is up / down / rising / falling / soaring / plummeting
High fidelity, low resolution, peak performance
A steep temperature gradient
Prices have fallen through the floor
Harry raised his bid
House prices have risen out of reach of the first time buyer.
- (42) TIME IS A MOVING OBJECT:
In the following weeks...
In the preceding days...¹³
The time will come...
The time has arrived
The hours passed / crept / crawled / dragged / sped / whizzed by.
- (43) ARGUMENT IS WAR:
Your position is undefensible
He attacked every weak point in my argument
His criticisms were right on target
I've never won an argument with him
You disagree? Okay, shoot!
If you use that strategy, he'll wipe you out
He shot down all of my arguments
The big guns in the audience were ready to shell Professor X's position.

Systematic metaphors are conventionally named with a short mnemonic name written in capitals, so MORE IS UP, TIME IS A MOVING OBJECT, and ARGUMENT IS WAR are three systematic metaphors. Each of these systematic metaphors has an underlying analogy, called its 'core analogy'. MORE IS UP reflects the analogy between an increasing and decreasing quantity and a rising and falling object. TIME IS A MOVING OBJECT reflects an analogy between the elapsing of time and the movement of a physical object. ARGUMENT IS WAR reflects a complex analogy between a proponent and a critic of an argument and military defenders and attackers.

The individual metaphors which come under the umbrella of one of these systematic metaphors are termed 'manifestations', so that

¹² The naming of these core metaphors is due to Lakoff and Johnson, and is only intended to be a labelling for convenience and not necessarily an accurate statement of the core metaphor.

¹³ It is arguable whether 'preceding' should be considered primarily as a temporal word or a spatial word. 'Before' is a word that is similarly ambiguous.

(44) *The summer rolled by*

is a manifestation of TIME IS A MOVING OBJECT. The analogy underlying this manifestation is an elaboration of the core analogy of TIME IS A MOVING OBJECT.¹⁴

Lakoff and Johnson show systematic metaphor to be extremely pervasive in everyday language – they identify some fifty examples which cover a very wide range of metaphors, both live and dead [see Appendix B], and it is not hard to find more.

Systematic metaphor seems to be very deeply rooted in the language, even manifesting itself at the etymological level:

(45) MORE IS UP:

He is underage

It is overdone

Tom underestimated its value, so undercharged Harry

Dick overcompensated for the fall in the dollar, and overspent his budget

We must upgrade our facilities.

This metaphorical structure among word senses can be quite complex, as, for example, in Michael Reddy's 'conduit metaphor' [Reddy 79]. This underlies much talk about communication, seeing ideas as objects which are packaged in messages (containers) and sent along a conduit to be unpacked by a hearer:

(46) IDEAS ARE OBJECTS

LINGUISTIC EXPRESSIONS ARE CONTAINERS

COMMUNICATION IS SENDING:

It's hard to get that idea across to him

I gave you that idea

None of Mary's feelings came through to me with any clarity

Whenever you have a good idea practise capturing it in words

Try to pack more thoughts into fewer words

The sentence was filled with emotion

The lines may rhyme, but they are empty of both meaning and feeling

Thus a 'dead' metaphor may exhibit few of the hallmarks of metaphor in a local context, but when seen alongside other associated dead and live metaphors, the metaphorical processes at work are undeniable. Dead metaphors may have lost their metaphorical colour, but they retain their capacity to be extended, a capacity which is constantly being exploited. In view of this, I shall follow Cooper [Cooper 86] in preferring the term 'established metaphor' to the somewhat pejorative 'dead metaphor'.

¹⁴ It is perfectly possible for a metaphor to be a manifestation of more than one systematic metaphor.

Computational implications

In the light of this evidence, it is possible to see a distinct disadvantage in the usual 'mere polysemy' approach of computational linguistics: when processing some utterance, if an appropriate word sense is not to be found in the system's dictionary there would seem to be very little scope for even an approximate interpretation – all that can be done is to look at senses of the word which *have* been listed in the dictionary and try to adapt them somehow to make sense of the utterance. But this puts the system in a difficult position; as Cooper puts it:

Why, for example, should attacking an argument not be, by analogy with 'attacking a good steak', relishing rather than criticizing the argument? Why shouldn't a knock-down argument, by analogy with 'knock-down prices', be an argument which has lost its value rather than a powerful argument against an opponent? Why shouldn't an abandoned argument be like abandoned behaviour – something to revel in – rather than an argument one has given up?¹⁵

Clearly, knowledge of two things would be of great value in these circumstances: firstly, knowing the systematic metaphor ARGUMENT IS WAR, and secondly, knowing which among the listed senses of **attack**, **knock-down**, and **abandoned** is the parent sense. This knowledge would indicate *which* of the known polysemes to adapt, and also give some guide as to *how* to adapt it. This is the approach taken in this thesis.

Literalness and core senses

This observation has an important contribution to make to the discussion of 'literalness'. It can now be seen that there *is* a genuine and useful distinction between 'literal' word senses and established metaphorical word senses: literal senses are parent senses, whereas metaphorical senses remain derivative in nature, but become so familiar and are processed so easily that their metaphorical nature is easily overlooked. To avoid later confusion,¹⁶ this singled out 'literal' sense will be referred to as the 'core sense' of a particular homonym. The term 'core' is preferred to, say, 'original', since the concern in this work is primarily with synchronic derivation of new word senses; this relies on current intuitions about what is a core sense, and these intuitions might be at variance with the historical origins of a word.

In general, one might expect to be able to identify a single core sense for each homonym, with all metaphorical polysemes within a homonym being derived in some way from this single core sense. In view of the difficulty of distinguishing homonymy and polysemy, as pointed out above, this expectation would appear to be a simplification of the real situation.

¹⁵ [Cooper 86] p. 132

¹⁶ Later, a concept of literalness *with respect to a computer application* is developed.

In what follows, however, it will be assumed that a single core sense *can* be found for each homonym, and furthermore, the existence of more than one homonym for a particular word-form will generally be ignored. Thus attention will be focused on how metaphorical polysemes are derived from core senses.

2.3 Why use metaphor?

Having now gained an idea of the occurrence of metaphor in English, it is only natural to ask why speakers use metaphor in the first place. There would seem to be no single answer other than 'for a variety of reasons'. This short section is intended to review a few suggestions which have been made, and these suggestions offer significant insight into what a computationally useful theory of metaphor should seek to explain.

Poetic and rhetorical effect

Probably the most obvious motivation for using metaphor is to achieve some sort of poetic effect. The speaker seeks to convey some unusual image to the hearer, thus enabling him to manipulate the hearer's subjective reaction.

(47) *Juliet is the sun*

conveys images of Juliet as radiant and dazzling, evoking positive feelings in the hearer, whereas

(48) *Who would bear the whips and scorns of time?*

evokes very negative reactions associated with 'whips' and 'scorns'.

This idea of influencing the hearer's attitudes can also be seen in somewhat more prosaic metaphors, and so metaphors are important weapons in the armoury of rhetoric. They highlight certain features which the rhetorician wants to be prominent in his audience's mind, and play down others, which are perhaps damaging to his argument.

For example, commenting on privatization:

(49) *The government is freeing industry from the shackles of state control*

emphasizes the restrictions of state ownership on nationalized industries and arouses feelings associated with release from bondage, whereas

(50) *The government is selling off the family silver*

emphasizes that nationalized industries are national assets, and has connotations of shame.

This point is further exemplified by Lakoff and Johnson, where they cite the use of systematic metaphors deliberately chosen to suggest a particular course of action to the hearer:

For example, faced with the energy crisis, President Carter declared "the moral equivalent of war." The WAR metaphor generated a network of entailments. There was an "enemy," a "threat to national security," which required "setting targets," "reorganizing priorities," "establishing a new chain of command," "marshaling forces," "imposing sanctions," "calling for sacrifices," and so on and on. The WAR metaphor highlighted certain realities and hid others. The metaphor was not merely a way of viewing reality; it constituted a license for policy change and political and economic action.¹⁷

This metaphorical highlighting depends on the speaker drawing attention to some commonality between the source and target. For more complex similarities, the term 'analogy' would seem more appropriate, and extended metaphors are often employed. A rhetorical example of such an extended metaphor is Arnold Toynbee's comment on American foreign policy:

- (51) *America is a large friendly dog in a small room. Every time it wags its tail, it knocks over a chair.*

There are also numerous didactic metaphors expressing analogy, such as

- (52) *The atom is a tiny solar system, the nucleus is the sun and electrons are the planets.*

Filling gaps in the lexicon

A frequently suggested reason for using metaphor is that there are simply not enough words in the language to express what needs to be expressed. The problem is particularly acute in more abstract domains, where concepts are inevitably more remote from pre-existing vocabulary. When talking of the mind, for instance, attention, allegiance and respect are 'paid', 'shifted', 'gained', and 'lost'. When a new technology is developed, it is easier to use suggestive old words to convey meaning than to coin lots of new words. For example, the terminology used in the field of computing abounds with metaphors such as 'memory', 'stacks', 'pointers', 'garbage collection', 'routines', 'procedures', 'programs', and so on.

¹⁷ [Lakoff and Johnson 80] p. 156

This point is further exemplified by Lakoff and Johnson, where they cite the use of systematic metaphors deliberately chosen to suggest a particular course of action to the hearer:

For example, faced with the energy crisis, President Carter declared "the moral equivalent of war." The WAR metaphor generated a network of entailments. There was an "enemy," a "threat to national security," which required "setting targets," "reorganizing priorities," "establishing a new chain of command," "marshaling forces," "imposing sanctions," "calling for sacrifices," and so on and on. The WAR metaphor highlighted certain realities and hid others. The metaphor was not merely a way of viewing reality; it constituted a license for policy change and political and economic action.¹⁷

This metaphorical highlighting depends on the speaker drawing attention to some commonality between the source and target. For more complex similarities, the term 'analogy' would seem more appropriate, and extended metaphors are often employed. A rhetorical example of such an extended metaphor is Arnold Toynbee's comment on American foreign policy:

- (51) *America is a large friendly dog in a small room. Every time it wags its tail, it knocks over a chair.*

There are also numerous didactic metaphors expressing analogy, such as

- (52) *The atom is a tiny solar system, the nucleus is the sun and electrons are the planets.*

Filling gaps in the lexicon

A frequently suggested reason for using metaphor is that there are simply not enough words in the language to express what needs to be expressed. The problem is particularly acute in more abstract domains, where concepts are inevitably more remote from pre-existing vocabulary. When talking of the mind, for instance, attention, allegiance and respect are 'paid', 'shifted', 'gained', and 'lost'. When a new technology is developed, it is easier to use suggestive old words to convey meaning than to coin lots of new words. For example, the terminology used in the field of computing abounds with metaphors such as 'memory', 'stacks', 'pointers', 'garbage collection', 'routines', 'procedures', 'programs', and so on.

¹⁷ [Lakoff and Johnson 80] p. 156

Economy

There is also no doubt that a well chosen metaphor can be a great deal more concise than a corresponding literal expression of the same ideas. Compare

(53) *Time flies*

(54) *Time appears to elapse very quickly.*¹⁸

An interesting explanation of this economy is that a metaphorical utterance forces a hearer to deepen his thinking, so that he appreciates ideas and feelings which would otherwise need to be said explicitly.

Social intimacy

A social aspect of metaphor, pointed out by Ted Cohen and picked up by Cooper [Cohen 78], [Cooper 86], is that the use of metaphor, like the telling of jokes or the use of a private language, helps to cultivate a certain intimacy between the speaker and hearer:

There is a unique way in which the maker and the appreciator of a metaphor are drawn closer to one another. Three aspects are involved: (1) the speaker issues a kind of concealed invitation; (2) the hearer expends a special effort to accept the invitation; and (3) this transaction constitutes the acknowledgment of a community. All three are involved in any communication, but in ordinary literal discourse their involvement is so pervasive and routine that they go unremarked. The use of metaphor throws them into relief, and there is a point in that.¹⁹

Primacy

Seemingly against all these explanations of why speakers should employ metaphor, there is the long-standing thesis of what Cooper calls 'the primacy of metaphor'.²⁰ This thesis has it that far from being somehow bizarre, metaphor is the normal mode of human thought and this is reflected in natural language. So-called 'literal truth' is really a consequence of a metaphorical truth that has become so well established that nobody notices its metaphorical nature. A chair is not called a chair because it 'is' a chair in any absolute sense, it is only called a chair by a metaphorical extension of some prior conception of 'a chair'. Cooper quotes Nietzsche:

What then is truth? A mobile army of metaphors, metonymies, *etc.* ... which after long usage seem to a people fixed, canonical and binding. Truths are illusions of which one has forgotten that this is what they are –

¹⁸ It is impossible to avoid using dead metaphorical terms of speed.

¹⁹ [Cohen 79] p. 6

²⁰ Cooper discusses this at length in [Cooper 86] pp. 257-279.

metaphors that have become worn out and without sensuous force; coins that have lost their face and are considered, no longer as coins, but as mere metal.²¹

Similar observations about the 'myth' of objective truth, how there is a sort of cultural 'received' objectivity which is perpetuated in language, are made at length by George Lakoff and Mark Johnson [Lakoff and Johnson 80], [Lakoff 87].

This view at first sight may seem a little extreme, seemingly flying in the face of conventional attitudes towards the objective nature of truth; after all, surely a chair *is* a chair and a book *is* a book, surely there is no metaphor involved. This, however, is to look only at the extremes of the scale of description. The primacy view considers these apparently clear cut cases to be the most 'worn' examples, and in other examples the distinction between metaphorical and literal is nothing like so obvious. The primacy theory replaces the notions of literal and metaphorical with a continuum of, say, 'familiarity', and this is consistent with many of the observations made in this chapter. The diachronic evidence of etymology and the synchronic evidence of systematic metaphor would seem to lend considerable support to the primacy thesis, as many current word senses can be seen to have derived from metaphorical roots.

This realization of the central place of metaphor in language has been less than evident in previous theoretical approaches to metaphorical interpretation, such as those outlined in the next section, and has certainly been lacking in computational approaches, where metaphor has been firmly labelled as aberrant. This apparent attitude of setting metaphor apart has attracted justified criticism, but it should be realized that the primacy view *increases* the need to find a good mechanism for interpreting metaphors, since this same mechanism would then be simultaneously valid for so-called 'literal' interpretation. Certainly the mechanisms generally proposed for literal interpretation do not seem to be readily extensible to cover metaphor. One of the major points to recommend the computational theory of metaphor developed in this document, is that it turns out to be remarkably consistent with the idea of primacy, although the deeper philosophical questions of the nature of truth, metaphorical or otherwise, are not specifically addressed.

2.4 Theories of metaphor

The final part of this examination of the linguistic and philosophical context of this work is a short discussion of the currently predominant theories of metaphor comprehension. These theories are almost always aimed at explaining how sense can be made of 'novel' metaphors considered in isolation, they would require some development to cover the phenomenon of

²¹ [Nietzsche 79] p. 314, [Cooper 86] p. 258.

systematic metaphor. Nevertheless, they cover much of the groundwork for the computational theory of systematic metaphor developed in the next two chapters.

2.4.1 The serial process approach

The common idea behind many, and probably most, of these theories is what might be termed the serial process approach to metaphor comprehension. This is that on hearing an utterance, (a) a hearer has to identify whether or not the utterance is literal, (b) if it is not, he must then identify the trope being used, and (c) he must interpret the utterance in an appropriate way to find its intended meaning. These three stages can be termed 'recognition', 'classification', and 'interpretation'.²² Of these, the interpretation stage is the one that most specifically requires a theory of metaphor.

Recognition

Broadly, two recognition strategies have been predominant: 'semantic anomaly' and latterly 'pragmatic anomaly'. The semantic anomaly approach involves looking for nonsensical sentences, that is, sentences where the words used are semantically incompatible. For example,

- (55) *Harry erupted*
- (56) *Tom is a cabbage.*

This semantic anomaly test cannot, however, detect irony, hyperbole, or litotes. It also has a deeper failing in that it cannot recognize sentential metaphor, such as was seen in examples (25)–(27), or the second sentence in Levinson's example:

- (57) A: *What kind of mood did you find the boss in?*
B: *The lion roared.*²³

In such examples of sentential metaphor there is no semantic anomaly, as, by definition, a semantic interpretation is possible. What is required is an appeal to pragmatics – the sentences must not be considered in isolation, but rather as part of a discourse, with due consideration given to context. Levinson gives such a pragmatic account of the recognition phase by appeal to Grice's maxims of quality, quantity, relevance, and manner [see Glossary]: if a literal reading appears to 'flout' one or more of these maxims, then the utterance displays 'pragmatic infelicity', and a non-literal interpretation is called for to remedy the situation [Levinson 83]. For example, in (57), the literal interpretation of the

²² Following [Cater 87].

²³ [Levinson 83] p. 153.

second sentence flouts the maxim of relevance. In other sentential metaphors, such as

(58) *Mrs. Thatcher reduced Mr. Kinnock to mincemeat*

the literal interpretation flouts the maxim of quality (which requires the speaker to speak truthfully).

Clearly *both* semantic and pragmatic approaches are required, since the testing of a literal interpretation for pragmatic felicity presupposes that a literal meaning can be found. For the computational linguist, semantic anomaly, being a local phenomenon, is the easier part of the problem and can be dealt with, for example, by considering selection restrictions on the arguments of predicates. Pragmatic infelicity is much less clearly defined and currently, for the most part, beyond the state of the art. There are one or two pragmatic phenomena, however, which *can* be dealt with: a computational system with only a semantic capability could detect blatant truths and falsehoods, such as

(59) *No man is an island*

(60) *All the world's a stage*

(which flout the maxims of quantity and quality respectively); and a basic discourse handling capacity would mean that flouting of the maxim of relevance due to metaphorical definite reference could be detected, as, for example, in (23) and (57).²⁴

The theory of descriptive analogy developed in the next two chapters recognizes the rôles of both semantic and pragmatic anomaly, and the MINT system which implements this theory uses a hybrid test with both semantic and pragmatic elements. In particular, reference resolution is carried out prior to the test for anomaly.

Classification

After the use of non-literal language has been recognized, the serial process approach requires the classification of an utterance to identify the trope being used. This is not easy. In principle, both metaphor and metonymy can give rise to semantic anomaly, and all the tropes mentioned above, bar simile, give rise to pragmatic infelicity.²⁵

The pragmatic anomaly test, then, merely identifies a sentence as non-literal, and fails to distinguish between metaphor and metonymy, irony, hyperbole, and litotes. The means by which they can be discriminated can be seen to involve a deep appreciation of a discourse, with substantial inference and appeal to 'world knowledge': in Searle's example [Searle 79]

(61) *It's getting hot in here*

²⁴ Assuming, of course, that context gives no alternative referents for 'the disease' and 'the lion'.

²⁵ Simile stands out as an exception, as it is generally regarded as literal, involving neither semantic anomaly nor pragmatic infelicity.

contexts can be imagined where the utterance is intended literally (if it is indeed becoming hot in the place of utterance), ironically (if the temperature is in fact decreasing), hyperbolically (if it is in fact only getting warm), litotically (if it is becoming really unbearable), or metaphorically (if an argument is getting more angry).²⁶

The situation is further complicated by the fact that more than one trope can be in play at the same time.

This thesis does not address the issue of classification, and from now on metaphor is assumed.

Interpretation

Assuming now that a metaphorical utterance has been encountered and identified the remaining task of interpretation is somehow to discover the utterance meaning – what was the speaker trying to communicate?

There are two predominant theories of how to recover this meaning, they are known as the 'comparison theory' and the more advanced 'interaction theory'. These are now described in some detail.

2.4.2 The comparison theory

The comparison theory is essentially that metaphors are compressed, or 'elliptical', similes. The meaning of a metaphor is therefore an assertion of similarity, so the interpretation phase can be subdivided into a 'reconstruction' phase, where a literal paraphrase of the metaphor is constructed, followed by a literal interpretation phase, in which this literal reconstruction is interpreted in just the same way as any other literal sentence is interpreted.

In this view, the non-literalness of a metaphor is due to the omission of a few words explicitly indicative of similarity. So, for example, (62) can be reconstrued to give the literal utterance (63):

(62) *Man is a wolf*

(63) *Man is like a wolf.*

This reconstruction can get rather involved, and the resulting literal paraphrase correspondingly clumsy. For example, trying to repair (18) gives something like (64):

(64) *Mrs. Ghandi did something that was like something steaming ahead.*

²⁶ Searle omitted the hyperbolic and litotic readings, but added an indirect speech act reading (asking the hearer to open a window) assuming literal truth. In fact an additional indirect speech act along the lines of "... and please do something about it" could be implicit in all the given readings.

An advanced account along these lines is given by George Miller in his paper *Images and Models, Similes and Metaphors* [Miller 79]. He presents a number of formal rules for constructing just such literal paraphrases from his three classes of metaphor (nominal, predicative, and sentential), working in a sort of logical form. For example, (18) is rendered as the logical equivalent of (64):

$$(65) (\exists F)(\exists y)\{\text{SIM}[F(\text{Mrs. Gandhi}),\text{STEAMING-AHEAD}(y)]\}$$

The comparison approach is successful in delivering a literal paraphrase with explicit assertions of similarity, but it seems to stop short of a full interpretation: (64) may be literal, but what does it *mean*?

Truth-conditional semantics has it that the meaning of a sentence is the set of 'truth-conditions' under which that sentence can be said to be true, but this quickly runs into a problem for similes: everything is like everything in at least some respect, so the mere assertion of similarity is vacuous, it is trivially true – any simile, and so any metaphor, becomes a tautology, devoid of meaning in the truth-conditional sense.

Ortony [Ortony 79b] gets round this tautological objection, allowing him to have comparisons which are false, by considering only 'high salience' predications of the source and the target.²⁷ Consider, for instance, the two similes

(66) *Encyclopaedias are like dictionaries*

(67) *Encyclopaedias are like gold mines.*

Encyclopaedias and dictionaries do share high salience predicates, but encyclopaedias and gold mines share none. Therefore, argues Ortony, (66) should in fact be classified as a 'literal comparison', and is literally true, whereas the term 'simile' should be reserved for the more involved (67), which is literally false (and should be interpreted metaphorically).²⁸ There is, unfortunately, a problem with this line of argument, which is that salience is a matter of degree and not an absolute, so literal truth should also be a matter of degree. Consider the intermediate example

(68) *Encyclopaedias are like reference libraries*

is this a literal comparison or a simile?²⁹

In view of these comments, perhaps a more apt way of describing the relationship between simile and metaphor would be to say not that a metaphor is an elliptical simile, but that a simile is an explicit metaphor – producing a simile paraphrasing a metaphor leaves much interpretive work still to be done.

²⁷ The terms 'source' and 'target' can be extended to apply to similes as well as metaphors.

²⁸ Note that this is *not* saying that a simile is not literal, a statement can be literal or not literal, and if literal, it can be true or false.

²⁹ Earl MacCormac builds a theory of metaphor on just such an idea of degree of truth, using a four valued logic running through 'true', 'epiphor', 'diaphor', 'false' [MacCormac 85].

What is required is an insight into *how* the source and target are similar. What similarities was the speaker intending to convey? This is the fundamental problem with the comparison theory, a problem which is addressed squarely in the interaction theories.

2.4.3 The interaction theory

The interaction theory of metaphor, due originally to Max Black [Black 62], [Black 79], says that the interpretation of a metaphor can be achieved by consideration of its source and target domains and how they interact. The interaction theory can be regarded as an *extension* of the comparison theory – both maintain that a metaphor involves similarities, but the interaction theory goes further in analyzing the nature of these similarities.

Black's original theory

Black's own summary of his interaction theory is as follows: [with explanatory comments added here in square brackets]³⁰

- (1) A metaphorical statement has two distinct subjects, to be identified as the "primary" subject and the "secondary" one. [These are what have been described here as the target and the source domain]
- (2) The secondary subject is to be regarded as a system [a conceptual domain] rather than an individual thing.
- (3) The metaphorical utterance works by "projecting upon" the primary subject a set of "associated implications," comprised in the implicative complex, that are predicable of the secondary subject. [i.e., implications, or statements, that can be made about the source are applied to the target via some 'projection' mechanism]
- (4) The maker of a metaphorical statement selects, emphasizes, suppresses, and organizes features of the primary subject by applying to it statements isomorphic with the members of the secondary subject's implicative complex. [Since statements about the *source* are applied to the target, the metaphor maker, in his choice of source, effectively selects features of the target to highlight and conversely plays down others].
- (5) In the context of a particular metaphorical statement, the two subjects "interact" in the following ways: (a) the presence of the primary subject incites the hearer to select some of the secondary subject's properties; and (b) invites him to construct a parallel implication-complex that can fit the primary subject; and (c) reciprocally induces

³⁰ [Black 79] p. 28

parallel changes in the secondary subject [such changes are due to the highlighting and downplaying of source and target features in the hearer's mind].

This theory is consistent with many of the observations on metaphor made in this chapter, such as the observation that a metaphor has a source and a target and that the interpretation relies on noticing a similarity between the two. It goes further than the comparison theories in that the interpretation of a metaphor is put down to the transference of features from the source's 'implicative complex' to the target, and the nature of these features explains how metaphors can highlight some features of the target and play others down. In choosing the source appropriately, this highlighting and down-playing is under the control of the speaker.

Black's interaction theory, however, uses rather general terms, like 'properties', 'projection', and 'implication-complex'. These need making much more specific before the theory can be adopted by the computational linguist. Also, as it stands, the theory says nothing about the phenomena of established, extended, and systematic metaphor.

Developments of the interaction theory

More theories *have* been proposed that fit into the mould of the interaction theory, but which are more specific in the operation of interpretation. These mostly rely on representing properties as 'semantic markers' – atomic features that may be positively attributed to some entity (e.g. +MALE), negatively attributed (e.g. -MALE), or simply not specified.³¹

In these schemes; projection is seen as the transference of a subset of the source's semantic markers to the target, the other markers having been 'cancelled' (these cancellation and transference operations constitute the 'interaction' between source and target).

Such an account is given in the context of other linguistic devices involving marker cancellation by Jonathan Cohen [Cohen 79]. For example, in the metaphor

(69) *Their legislative program is a rocket to the moon*

the target, the legislative program (*sic*), induces a cancellation of certain markers in the source, 'a rocket to the moon'.³² Thus markers such as +MATERIAL, +AIR-CLEAVING and +CYLINDRICAL are dropped, leaving markers such as +FAST-MOVING and +FAR-AIMING.³³

Cohen goes on to address the problem of which markers should be cancelled; he proposes a notion of 'semantic importance' to rank markers and guide the cancellation process, though this idea is not fully developed in the paper.

³¹ There are, of course, some variations on this theme. See for example [Lyons 77].

³² Cohen's terminology is 'topic' and 'comment' for target and source.

³³ Cohen contrasts this metaphorical cancelling of markers from the comment with 'literal' cancelling of markers from the topic: in "The stone lion" the source 'stone' causes markers such as +ANIMATE to be dropped from the target.

A much more detailed account involving semantic markers in noun-verb sentences is given by Samuel Levin in his book *The Semantics of Metaphor* [Levin 77].

Levin proposes two modes of marker adjustment, which he collectively terms 'adjunction'. The first of these is 'disjunction', where semantically incompatible markers are cancelled,³⁴ and the second 'conjunction', where markers are pooled. The direction of either of these forms of adjunction can be either from the verb to the noun (so the 'meaning' of the noun is altered) or from the noun to the verb (thus modifying the 'meaning' of the verb).

Consider, for example, the predicative metaphor

(70) *The stone died.*

'Stone' has a number of semantic markers, the ones relevant here are +MINERAL, +NATURAL and +PHYSICAL. Similarly, 'die' is supposed to be predicable of things with markers +HUMAN and +NATURAL.

Adjunction gives four readings for (70):

- a) $N \leftarrow V$; disjunction: The natural physical object died. [+MINERAL dropped from 'stone']
- b) $N \leftarrow V$; conjunction: The stone (as if human) died. [+HUMAN added to 'stone']
- c) $N \rightarrow V$; disjunction: The stone ceased to exist. [+HUMAN dropped from the argument restriction of 'die']
- d) $N \rightarrow V$; conjunction: The stone died (as if 'die' were predicable of objects jointly human and mineral).

In addition to adjunction, there is a process of 'displacement', which simply allows one word to stand for another in a nominal metaphor. These words can be recovered by a simple 'look-up' operation.

This gives a further two readings for (70), say,

- e) $N \leftarrow V$: The dolt died.
- f) $N \rightarrow V$: The stone disintegrated.

making six readings in all.

This theory has the attractive feature of seeming to explain the imagery of metaphor – the idea of seeing things in new ways – through the conjunctive readings, and simultaneously giving literally interpretable readings through disjunction or displacement.

³⁴ The notion of incompatibility is made formal in Levin's book, but is not of direct relevance to the argument here.

2.4.4 Problems with these theories

Representing relationships

The mechanism of interaction through semantic marker manipulation, however, has an inherent problem. Markers as presented above are very isolationist in application. Giving a rocket to the moon the markers +MATERIAL, +AIR-CLEAVING, +CYLINDRICAL, +FAST-MOVING and +FAR-AIMING says much about a rocket to the moon, but nothing about the relationships between a rocket and associated entities, such as its launch pad, its designer, its crew, and so on. In cases of *extended* metaphor and *systematic* metaphor, such relationships are of central importance. Consider the example

(71) *You are my honeysuckle, I am the bee.*

What is most important here is the relationship between honeysuckle and bees, their individual properties are of lesser concern. Semantic markers are not suited to capture this sort of knowledge, and a much richer representation is required for a treatment of extended and systematic metaphor.³⁵ Even if honeysuckle had a marker, say, +ATTRACTIVE-TO-BEES, there is no mechanism for making use of this. Although the *name* of the marker appears meaningful to a human reader, as far as a computational system would be concerned, a marker is simply a marker – its name is simply a meaningless string of characters.³⁶

This problem of non-meaningful names, however, is a problem associated with the use of semantic markers, and not a problem for the interaction theory *per se*. What is required to provide a better realization of the theory is an improved representation covering relationships for the semantics of the source. This is clearly indicated by Black himself when he says “The secondary subject is to be regarded as a system rather than an individual thing”.

The recursive nature of metaphor and abstraction

There is, however, a problem highlighted by the semantic marker system, but which is general to the interaction theory. It is this: the markers that end up being applied to the target of a metaphor, or simile, are very often valid only in a *metaphorical* sense. This can be clearly seen in Cohen’s analysis of (69). For a moon rocket to be ‘fast-moving’ and ‘far-aiming’, and a legislative programme to be ‘fast-moving’ and ‘far-aiming’ are quite different things. In the particular case of semantic markers this problem would appear to be

³⁵ It is possible to extend the semantic marker system to include some relational information [see Lyons 77 section 9.9], but it is not easy to see how the mechanisms for metaphor interpretation presented above could be extended to make use of this.

³⁶ It is difficult for a human reader not to read and write meaning into marker names, and this can lead to confusion. The term ‘markerese’ has been coined to draw attention to this pitfall [Lewis 72].

insurmountable, as markers are supposed to be absolute and atomic in meaning, there should be no scope for interpreting the *name* of a marker metaphorically.

It is worth dwelling on this 'recursive' property of metaphors – having to interpret markers (or 'properties' in a more general framework) metaphorically – as it is central to the operation of systematic metaphor and so of great importance in this thesis. What we have seen so far in the interaction mechanism³⁷ is a process of 'abstraction' – as more and more features are dropped from the source, the resulting semantic concept becomes more and more abstract, encompassing more and more entities or situations. So, for example, to make 'die' cover the end of a stone, it is *abstracted* to mean 'cease to exist'.

Abstraction has proved useful in many examples of metaphor, and seems to form an integral part of metaphorical interpretation. On its own, however, abstraction is not sufficient for those examples requiring the recursive metaphorical interpretation of properties. Abstracting 'a rocket to the moon' enough to encompass a legislative programme leaves very little semantic information, whereas the intended metaphorical meaning of the phrase is something much more specific.

Consider Searle's example

(72) *Sally is [like] a block of ice.*

The intended meaning of this utterance is that Sally is unemotional. Abstracting 'a block of ice' leaves only properties like 'physical object' and 'composed of water'. This is not very enlightening as an interpretation. The property we *need* to interpret (72) is 'cold', which must itself be interpreted metaphorically as 'unemotional' *by appeal to the known systematic metaphor* EMOTIONALITY IS TEMPERATURE, the systematic metaphor behind the terms 'warm', 'cold', 'fiery' and so on when applied to people. Similarly, the example

(73) *Queen Victoria was made of iron*

requires the same sort of metaphorical interpretation of properties such as 'hard', 'resilient' and 'inflexible' using systematic metaphors such as OPEN MINDEDNESS IS FLEXIBILITY.

A pragmatics objection

A final objection to these marker-based realizations of the interaction approach, one raised by John Searle [Searle 79], is that the mechanism of interaction acts at the semantic level, whereas it is necessary to act at the pragmatic level: In (70), semantic markers for the lexical 'stone' and 'die' are what interact, but in (72), "Sally" is a referring expression so is simply not semantically comparable to "a block of ice" – "Sally" has no markers of its own

³⁷ except in Levin's conjunction operation

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to be used as a basis for interaction. What is needed is a knowledge of the *referent* of "Sally", which in conventional linguistic accounts is not available until the pragmatic level of interpretation, *after* semantic analysis is complete. Fortunately for the computational linguist this is not such a problem, as the semantic / pragmatic distinction tends to be rather blurred. In particular, reference resolution can be done at an early stage of processing, allowing access to accumulated knowledge about the target, including so-called 'world knowledge'.

Summary

It can be seen, then, that although the interaction theory seems useful as a starting point for a computational theory of metaphor, it is in need of substantial modification and specification of details. Important among these changes are a more powerful representation, a way of capturing the recursive nature of systematic metaphor, and a greater rôle for pragmatics.

2.5 Previous computational approaches to metaphor

This section offers a brief survey of previous computational approaches to metaphor. There have been relatively few of these, possibly due to a conventional attitude that metaphor is some deviant form of language, indeed, it has been mentioned under the title of 'ill-formed input'. Nevertheless the computational treatment of metaphor offered in this thesis has been influenced by this earlier work, and seeks to improve upon it.

It must be emphasized at this point that this review of computational approaches to metaphor is limited in scope to their success, or otherwise, in accounting for the observations on metaphor made above. This is undoubtedly to do them an injustice in that in general they are not specifically intended to account for metaphor, but rather they are attempts to broaden the scope of existing schemes to include particular metaphorical phenomena. In other words, they were never intended, for the most part, to be theoretically valid, but were engineering solutions to particular problems.

2.5.1 Early work

Preference Semantics

One of the earliest proposals came from Yorick Wilks [Wilks 77, 78], where he developed a strategy for dealing with 'extended word use' in his preference semantics system.³⁸ In outline, preference semantics (PS) is a system capable of resolving certain linguistic ambiguities by consideration of the argument preferences of verbs. For example, when faced with the sentence

(74) *The policeman interrogated the crook*

preference semantics selects (75) in preference to (76) because in the former the preferences of 'interrogate' for a human actor and a human object are satisfied, whereas in the latter a preference is broken:

(75) [policeman] [interrogated] [crook (man)]

(76) [policeman] [interrogated] [crook (thing)]

The square brackets notation is shorthand for the semantic primitive expansion of the enclosed word or words.

In general, though, not *all* preferences needed to be satisfied in the then extant version of preference semantics [Wilks 75], the system simply accepted the reading with the *most* satisfied preferences. Thus

(77) *My car drinks gasoline*

was accepted by preference semantics at face value, even though the preference of 'drinks' for an animate actor is broken. This was not unreasonable in the envisaged application of machine translation, where the metaphor could be translated as it stands, as, say, "*Ma voiture boit de l'essence*", but for a different application, where a deeper understanding was required, an extended use of 'drinks' would need to be captured.

The proposal that Wilks made for this was that the offending 'template' (actor-action-object combination) should be somehow matched against templates in a sort of encyclopaedia entry for [car], called a 'pseudo-text'; the best match, if any, should be 'projected' onto the original formula by replacing its action semantics. Thus

(78) [my+car drinks gasoline]

matches

(79) [engine uses #liquid]³⁹

³⁸ An implementation based on these ideas is given by Fass [Fass 88a].

³⁹ The # symbol indicates a 'thesaurus entry'.

in the pseudo-text for [car], and projection yields

(80) [my+car uses gasoline]

Ignoring the detailed problems of how this matching and projection might be done, the underlying strategy of this approach is to match a semantically anomalous utterance against a body of world knowledge and to project the matching item onto the original utterance, giving a semantically well formed result.

There is good potential in this method for obtaining very specific interpretations of metaphors, but there is an obvious problem, which is that an encyclopaedia entry must anticipate the general meaning of all potential metaphorical utterances if a match is to be found at all. For example, the utterances

(81) *My car spits gasoline all over the road*

(82) *My car bleeds oil*

would require encyclopaedic knowledge about faulty cars as well as typical cars. Also, this particular approach does not seem to offer any insight into how systematic metaphor might be handled.

Some further proposals as to how extended word uses could be interpreted, rather than merely tolerated, in preference semantics are given in [Fass and Wilks 83]. The additional mechanisms do not involve world knowledge, but simply change the semantic heads (overall categories) of the meaning representation of either the offending noun phrase or the verb preference. So in (77), either [car] has its head changed from 'vehicle' to 'animate', or 'drinks' has its actor preference modified to include vehicles.

This treatment is similar to Levin's $N \leftarrow V$ and $N \rightarrow V$ conjunction described earlier, and is shown to be valuable in the machine translation task (where the metaphors are translated word for word), but it cannot really be called interpretation, as an animate car is not very much more meaningful than a drinking car.

2.5.2 Analogical approaches

The two analogical approaches to metaphor interpretation reviewed next, those of Carbonell and Indurkha, have strongly influenced the development of the theory of descriptonal analogy and the MINT system. Both accounts take the form of unimplemented proposals, and are theoretical in nature. Both, however, have the weakness of viewing metaphorical processing as significantly different from 'normal' linguistic processing, a weakness that descriptonal analogy seeks to overcome.

Carbonell

Jaime Carbonell in 1980 proposed an elaborate scheme to enable a computational system to exploit *systematic* metaphor [Carbonell 80, 82]. He too observed that systematic metaphor is extremely common in the sort of English that computational linguists should be interested in, and that the task of interpreting metaphors by appeal to known core analogies, rather than from first principles, should be both more feasible (since it relies on *recognition* rather than reconstruction) and useful.

His plan was to represent core analogies as structured objects, each having four main parts: (a) a 'recognition network' to identify instances of its use, (b) a 'basic mapping' to do the initial interpretation and so establish a framework for more subtle interpretation, (c) an 'implicit-intention' component to deliver stock pragmatic inferences (why the speaker used this particular metaphor), and (d) a 'transfer mapping' to do the more subtle interpretation not accomplished by the basic mapping.

This remains an unimplemented proposal, and the principal objection to it is that the somewhat unwieldy representation of these core analogies goes against the idea that metaphorical and literal interpretation should not be all that different in character. Carbonell himself says

Perhaps a more subtle process that integrates metaphor information more closely with other conceptual knowledge is required.⁴⁰

Nevertheless, the underlying *process* of interpretation, viz identification, skeletal fitting of the metaphor and filling in of details seems very plausible.

A later publication of Carbonell and Minton [Carbonell and Minton 85] goes into a little more detail about what the basic and transfer mappings might look like in a semantic network formalism. The essential point made is that these mappings must not only pair off individual entities as being alike, but must include reference to the *relationships* between groups of entities. Such relationships, they argue, are crucial in metaphor interpretation. Carbonell and Minton point out that such structured mappings would be good candidates for more informative IS-A links, thus linking metaphorical interpretation more closely with literal interpretation.

These ideas have been adopted in the theory of descriptive analogy and developed to the point where an implementation has been possible.

⁴⁰ [Carbonell 80] p.18, [Carbonell 82] p.418.

Constrained Semantic Transference

A very detailed treatment of what amounts to a realization of Carbonell's basic and transfer mappings has been developed by Bipin Indurkha in a series of recent publications [Indurkha 85, 86, 87]. Indurkha's approach is to develop a formal account of analogy in a predicate calculus notation, this he calls 'Constrained Semantic Transference', or 'CST'. He goes on to assert that metaphors can be understood by constructing and elaborating analogies, 'T-MAPs', between source and target domains, and using these T-MAPs to translate statements in the source domain to statements in the target domain.

The two domains involved are represented as two logical systems made up of a 'vocabulary' (names of functions and predicates of zero or more arguments) together with a number of logical statements, or 'structural constraints', which give relations between the various terms in this vocabulary. So, for example, the domain FAMILY has the terms *mother*, *father*, *parent*, *daughter*, *male*, and *female* in its vocabulary, together with constraints to the effect that mothers are female parents, and so on.

A T-MAP relates two domains by pairing off some of the vocabulary terms of its source domain with suitable terms in the target domain. Logical statements made in the source domain can then be interpreted by straightforward substitution of target terms for source terms as directed by the T-MAP, giving a new logical statement in the target domain. Clearly, not all translatable statements will be valid in the target domain, so a T-MAP also specifies a subset of its source domain's structural constraints which can be mapped to consistent target structural constraints.

An example of such a T-MAP would be between the FAMILY domain and the DAG domain ('DAG' for 'directed acyclic graph'). This T-MAP would pair off, for example, the term *node* in the DAG domain with *female* in the FAMILY domain, and *arc* with *mother*,⁴¹ and would specify a subset of the structural constraints of FAMILY such as $\text{mother}(x, y) \Rightarrow \text{female}(x)$ which are still valid when transformed into statements in DAG, e.g., $\text{arc}(x, y) \Rightarrow \text{node}(x)$.

The *static* view of T-MAPs (where T-MAPs are given and immutable) leads to a logical system where a pre-determined amount of the structure of a source domain is inherited via a T-MAP by a target domain. In the interpretation of novel metaphor, on the other hand, T-MAPs must be constructed *dynamically*, so that a statement involving both source and target terms can be translated to a statement involving solely target terms.

Indurkha outlines algorithms for doing this construction, including the interesting operations 'augmentation' and 'positing structure' both of which extend a T-MAP by incorporating

⁴¹ *mother* and *arc* are both regarded as two place predicates, the former being a relation between two people, and the latter between two nodes (i.e., the existence of a directed arc from the first to the second).

more terms from the source domain together with structural constraints relating them to terms already present. New vocabulary in the target domain is *created* to serve as the images of these newly incorporated source terms. For example, the T-MAP given above can be augmented by including the source term 'sibling', together with a definition of sibling in terms of parents and children. A new term such as 'DAG-sibling' is created in the DAG domain and as a result it possible to make sense of 'sibling nodes'. This creation of new terms in the target domain corresponds to metaphor extension and the creation of new metaphorical word senses.

Indurkha's work is of great value in formally linking metaphor to analogy and he points out at length how this view of the processes explains many empirical observations on metaphor. It is easy to see that core metaphors could be pre-coded as T-MAPs. The drawback of the approach, however, is that it is highly theoretical and unfortunately totally impractical from a computational point of view: Indurkha has couched his theory in terms of predicate calculus and model-theoretic semantics, and there is a consequent heavy burden of consistency checking to be managed. In the pure logical 'Constrained Semantic Transference' theory outlined above, Indurkha shows the problem of consistency checking to be theoretically insurmountable, and he attempts to get round this by using an approximation to CST called 'Approximate Semantic Transference' or 'AST', which is no longer logically kosher, but reduces the problem to one that is at least theoretically computable. Even this, though, remains unimplemented.

Another uncomfortable feature of the theory is that it depends on an extremely strong notion of domain. All knowledge in Indurkha's scheme is packaged into neat, isolated domains which are simply unrealistic in the rather messy real world with which natural language systems have to deal. The dominant status of the domain leads to a wide gulf between literal processing and metaphorical processing, which take place within and between domains respectively.

2.5.3 Practical systems

The preceding two treatments of metaphor have had most influence on the theory of metaphor developed in this thesis, but the following two computational treatments of metaphor come closest to the practical implementation of this theory in MINT. Both deal specifically and practically with systematic metaphor in a way that is closely related to their treatment of 'normal' language.

It is especially interesting that in both cases the motivation for giving a treatment of metaphor seems to have come from a practical experience of the ubiquity and apparent 'ordinariness' of metaphor in the two systems' chosen domains (naïve physics and

computing).

Hobbs

The first of these is work done by Jerry Hobbs as part of the SATE and DIANA discourse analysis systems [Hobbs 77, 79, 81].

Hobbs works using a predicate calculus based semantic representation and draws inferences by forwards and backwards logical reasoning from input representations and a list of 'axioms' which encode the systems' lexical and world knowledge. The precise details of the representation vary between the SATE and DIANA systems, but the gist of it is as follows:

The predicate *go*, say, has axioms associated with it which constitute a definition in terms of other predicates, such as *at* and *become*:

$$(83) \text{ go}(x, y, z) \ \& \ \text{at}(w1, x, y) \ \& \ \text{at}(w2, x, z) \rightarrow \text{become}(w1, w2)$$

This notation requires a little explanation, (83) should be read as follows: if *x* goes from *y* to *z*, and *w1* and *w2* are states such that *w1* is the state of *x* being at *y* and *w2* is the state of *x* being at *z*, then it can be inferred that there is a change of state from *w1* to *w2* – *w1* 'becomes' *w2*.

If an input is made of "John went to London" (from New York), which has the logical form

$$(84) \text{ go}(\text{John}, \text{NewYork}, \text{London})$$

then, using forwards and backwards reasoning, the system can make the inferences

$$(85) \begin{array}{l} \text{at}(\text{State1}, \text{John}, \text{NewYork}) \\ \text{at}(\text{State2}, \text{John}, \text{London}) \\ \text{become}(\text{State1}, \text{State2}) \end{array}$$

But, says Hobbs, if such an input is encountered, it should really be interpreted as "John flew to London in an aeroplane", to demonstrate proper understanding of the situation. This requires a process called 'predicate interpretation', which takes a general predicate like *go*, and interprets it as a more specific predicate like *fly-in-an-aeroplane*, depending on context. Predicate interpretation is achieved by having a series of axioms of the form

$$(86) \text{ specific-predicate}(\dots) \rightarrow \text{general-predicate}(\dots)$$

and choosing the right one to apply in the circumstances (in backward reasoning). This choice is effected in the system by dynamically reordering the axioms according to context, so that the most appropriate axioms are found and used first.

So far, this is all 'normal' processing, but Hobbs claims that systematic metaphor can be handled using the same mechanism of predicate interpretation. For example, a variable in

computer science can take a number of values; at any particular moment it is said to be 'at' a particular value. So in the context of variables, the general predicate *at* has a specific interpretation of *has-the-value*, and this axiom underlies a system of spatial metaphors for variables, metaphors such as

- (87) *N approaches 100*
- (88) *N goes from 1 to 100.*

The interpretation of these metaphors is achieved by specifying the axiom

- (89) $\text{variable}(x) \ \& \ \text{has-the-value}(w, x, y) \rightarrow \text{at}(w, x, y)$

and using predicate interpretation to interpret, for example, (88) as

- (90) $\text{has-the-value}(\text{State1}, N, 1)$
 $\text{has-the-value}(\text{State2}, N, 100)$
 $\text{becomes}(\text{State1}, \text{State2})$

Hobbs's work has made a significant contribution to the treatment of systematic metaphor in that it has exploited the idea that the addition of a single axiom, (89), (representing the systematic metaphor *VALUE IS LOCATION*) allows indirect interpretation of many metaphors, such as those that describe variables as 'going' and 'approaching'. Furthermore, he has done this in a way which does not treat metaphor as bizarre.

There is, however, a difficulty with this approach, which is that it makes no distinction at all between metaphorical and literal word senses, whereas it has been argued that there *is* a distinction to be made. The system relies very heavily on abstraction: predicates are made sufficiently abstract to encompass all possible uses; *at*, for example, is treated as a predicate applicable equally to both physical objects and variables. Since the meaning of *at* is now so abstract, it is difficult to see how, say,

- (91) $\text{at}(\text{State1}, \text{John}, \text{NewYork})$

can have anything but the vaguest of meanings (taking care not to interpret *at* as if it were the English word). It certainly does not have the specific meaning of *physically-located-at*. One way of tackling this problem of vacuous meaning would be to have a new specific predicate *physically-located-at* and the corresponding axiom

- (92) $\text{physical-object}(x) \ \& \ \text{physically-located-at}(w, x, y)$
 $\rightarrow \text{at}(w, x, y).$

In this case, predicate interpretation would be able to deliver the appropriate specialized interpretation. This, however, puts *physically-located-at* on a par with *has-the-value*, rather than as a distinguished core sense of 'at'. It was observed earlier that such distinguished senses are an essential requirement for systematic metaphor interpretation – metaphors should be interpreted by reference to a *core* sense, not some abstract sense.

Jacobs

The final work considered here also deals specifically with systematic metaphor. It is recent work done in the context of the Berkeley Unix Consultant system [Wilensky *et al.* 88], and is most fully developed by Paul Jacobs in [Jacobs 87, 88].⁴²

Jacobs's TRUMP natural language analyser is built on a development⁴³ of the KODIAK general knowledge representation system [Wilensky 87] – an advanced frame / semantic network representation, largely inspired by KL-ONE [Brachman and Schmolze 85].⁴⁴ Jacobs represents the knowledge behind systematic metaphors as a special kind of structured relationship between frames.⁴⁵ These relationships are specified by 'VIEW' links: the main link is between two frames and correspondences between slots of the frames are given by 'role-play' relations.

For example, the systematic metaphor ACTING IS GIVING which is manifested in examples like

(93) *John gave Mary a kiss*

is represented as a VIEW link between the transfer-event frame (which has slots for giver, object, and recipient) and the action frame (which has slots for actor and patient). This VIEW link specifies that the 'role' of the recipient in the transfer-event frame is 'played' by the patient in the action frame.

Interpretation of an input metaphor is achieved through the 'concretion' mechanism, which is a general method of speculating on a more specific reading of an input, analogous to Hobbs's predicate interpretation. ('Cut', for example, when applied to an 'edible-obloid', such as salami, is concreted to 'slice'). On encountering the input (93), initial interpretation results in an instantiation of the transfer-event frame (giving is a transfer event), whose object slot is filled by something which is a kiss and whose recipient slot is filled by Mary. The concretion mechanism of TRUMP is triggered by the presence of an action (the kiss) in the object slot, causing the instantiated transfer-event to be specialized to an action (that of kissing) whose patient slot is filled by Mary, as indicated by the role-play relation.

This work has several good features: it appears to be successful in interpreting a number of manifestations of systematic metaphor, the use of frames seems to be well suited to the representation of core analogies, and both literal and metaphorical examples are processed in a reasonably uniform way, using the concretion mechanism. Furthermore, all this occurs in a

⁴² A slightly different development of systematic metaphor in the UNIX Consultant system is given in [Martin 87, 88].

⁴³ 'Ace' [Jacobs 86]

⁴⁴ Jacobs treatment of systematic metaphor originated in his work on generation [Jacobs 86].

⁴⁵ These are not thought of as analogies by Jacobs.

system with a relatively large linguistic coverage.

This practical system for handling systematic metaphor, however, is not given any theoretical basis; Jacobs does not, for example, see VIEW links as representing analogies. Moreover, because of the complexity of the knowledge representation and the algorithms involved, the motivation behind TRUMP's processing is not very clear.

2.5.4 Summary of computational approaches

There have been relatively few computational attempts to deal with metaphor, and those that have been made have proved deficient in several important areas. Lessons to be learnt from this previous experience include:

- Metaphor interpretation relies on semantic knowledge.
- Core analogies should be represented in a semantic network using *structured* links.
- A strong notion of domain artificially widens the distinction between literal and metaphorical processing.
- The notion of frames is useful in the representation of analogy.
- It is possible to integrate literal and metaphorical processing, but this requires a better theoretical justification.

The computational account given in chapters 5 and 6 of this thesis can be seen to take account of all these observations.

2.6 Summary

In this chapter a number of significant observations about metaphor have been made, observations that will be taken into account in the theory of metaphor to be developed in the next two chapters. They include:

- (1) A metaphor describes some c-entity (its target) as though it were a different c-entity (the source), that is, the target is described using words drawn from the source domain. There may be more than one source or target involved.
- (2) Individual metaphors can occur at the word, phrase, or sentence level.
- (3) A metaphor reflects some analogy between its source(s) and target(s).
- (4) Extended metaphor occurs when this underlying analogy is re-used and developed during a text. In this way, whole texts can be regarded as metaphorical.

- (5) There is no easy way to separate the notions of 'literal' and 'metaphorical' – established metaphors can be seen to retain their metaphorical character even though they would generally be regarded as literal.
- (6) Established metaphors give rise to polysemous word senses which can be distinguished from their parent 'core' senses.
- (7) Systematic metaphor occurs when a single 'core' analogy can be seen to underlie many established and novel metaphors.
- (8) Systematic metaphor is very common.
- (9) Particular manifestations of a systematic metaphor should be interpreted by appeal to the core senses of words and the core analogy of the systematic metaphor.
- (10) Metaphors can highlight certain aspects of their targets and suppress others in the hearer's mind.
- (11) Recognition of metaphor depends on the detection of both semantic and pragmatic anomaly.
- (12) It is not easy to tell the various tropes apart without extensive pragmatic and world knowledge.
- (13) Reference resolution should occur at an early stage of the interpretation process.
- (14) Interpretation should involve abstraction, i.e., selective property inheritance.
- (15) Inherited properties can be fairly complex, so a complex semantic representation is required.
- (16) Inherited properties sometimes require recursive metaphorical interpretation, especially where systematic metaphor is involved.

Previous theories of metaphor have sought to explain many of these observations, but have principally concerned themselves with 'one-off' metaphors, interpreting them without appeal to knowledge of other metaphors, without admitting the recursive character of metaphor. Such theories have thereby neglected the phenomena of extended and systematic metaphor.

The next two chapters outline the new theory of 'descriptive analogy', which seeks (with considerable success) to explain these observations, while at the same time being sufficiently detailed that a practical implementation is possible. This implementation has been done in the MINT system, which is described in the subsequent two chapters.

3. Descriptive Analogy

In the last chapter much evidence has been seen concerning the occurrence of metaphor in English, and some of the theories from philosophy and linguistics which have been proffered in an attempt to explain why metaphor is used and how it can be interpreted. These theories offer valuable insights into the problem of how to interpret metaphors, but fall short of being computationally useful, either because they are couched in terms which are too vague to be implemented directly, or because they depend on a representational system, that of semantic markers, which is too weak to account for relational phenomena and defective in that it cannot account for the recursive nature of metaphor.

It is the aim of this chapter and the next to provide a new and computationally useful theory of metaphor, namely the theory of descriptive analogy, which is capable of explaining many of the observations made in chapter 2, and in particular covers the phenomenon of systematic metaphor, thus representing a significant advance over its predecessors.

The success of descriptive analogy stems from a remarkably simple premise, which is that descriptions are inherited across analogies. From this simple observation it is possible to derive principled and coherent mechanisms for producing paraphrases of both 'literal' and 'metaphorical' utterances. An important aspect of the approach of descriptive analogy is that all descriptions are treated as equally valid *as descriptions*. As far as the operation of description inheritance goes, no distinction is made as to whether a description is 'literal' or 'metaphorical', as both are seen as being derived from analogies – literalness is seen as a relative concept, only determined by reference to a particular (but arbitrary) dictionary, and therefore almost a matter of taste on the part of a lexicographer.

In this chapter, descriptive analogy is developed to a point where it can deliver literal paraphrases of metaphors using a sort of abstraction mechanism. This interpretive power is better than that of the theories discussed in the last chapter, since proper account is taken of relationships between entities. In the next chapter, this power is developed naturally to cover the phenomena of extended and systematic metaphor.

Overview

3.1 defines the importance of 'literalness' and 'well-formedness' as relative terms, relative to a particular dictionary. 3.2 sets out informally the sort of processing that is envisaged for interpreting manifestations of systematic metaphor and motivates the use of analogy. 3.3 takes a closer look at analogy and defines some terms. 3.4 introduces the formal theory of descriptive analogy and description inheritance. 3.5 covers c-entities and descriptions,

including the pivotal concepts of 'definitive entities' (ideal, 'archetypical' individuals) and their 'intrinsic' descriptions. 3.6 covers description inheritance from definitive entities. 3.7 describes how analogies involving definitive entities can be thought of as encoding both 'commonsense' knowledge and dictionary-style definitional knowledge. 3.8 shows how the analogies (with definitive entities) underlying input utterances (both literal and metaphorical) can be derived. 3.9 concludes the chapter by describing how descriptonal analogy can be used to interpret by abstraction, nominal, predicative, and sentential metaphors.

3.1 Literalness and well-formedness

The task which is to be addressed in this work, is to take instances of systematic metaphor and produce 'literal' paraphrases using knowledge of core analogies. As was seen in chapter 2, the notion of 'literal' is somewhat slippery, and so the first problem is to define what is to be regarded as 'literal'. The problem of finding a suitable definition of literalness is considerably eased by considering the question in the computational context, since it is much easier to quantify the various components of the system.

The dictionary and literalness

The initial idea of literalness presented in chapter 2 was that an utterance is 'literal' if it uses words and phrases in senses which appear in the dictionary. This was seen to be inadequate as it begs the question of whose dictionary to use. In the context of a computer system, however, the answer to that question is more obvious – the dictionary can be taken to be the machine's dictionary, giving a *system-dependent* idea of literalness.

This, however, leaves the question of which senses to include in the machine's dictionary. For the purposes of this work, the extreme position will be taken that only *core* senses are listed. The motivation behind this decision is that the potential of descriptonal analogy for explaining how metaphorical word senses can be derived from core senses is made more apparent. Later, in the discussion chapter, a natural way to incorporate further, polysemous word senses into the scheme is discussed.¹ The choice of which sense of a word to regard as the 'core' sense is sometimes debatable, but the important point is that only *one* sense is listed.

Relative to this unambiguous dictionary, then it is possible to specify what it means for an utterance to be literal – an utterance is said to be 'literal' if in its *intended* meaning words are being used in their core senses.

¹ For simplicity, other complicating factors, such as homonymy, are ignored.

It was pointed out in chapter 2 that an often cited reason for using metaphor is to fill gaps in the lexicon – in some cases, particularly in more abstract domains, a literal word with the required meaning is not available, so a word from another domain is used metaphorically. This metaphorical use of a word can be sufficiently well established that it appears in dictionaries, but in limiting a dictionary to core senses only, these gap-filling senses will be lost. Since such senses will sometimes be *needed* in a literal paraphrase, it will be necessary to coin new words to take their place. In this thesis, coined words will generally be formed by hyphenating a short phrase, so that they are at once mnemonic and marked as coined, and they will be used to demonstrate the *results* of interpretation in a relatively unambiguous way.

Well-formedness

In addition to a well-defined notion of literalness for utterances, it will be useful to define 'well-formedness'.² An utterance will be described as 'well-formed' if it is semantically well-formed, that is, if it is *capable* of being interpreted literally. This again is a system-dependent notion, being relative to the particular dictionary in use. Since the working assumption here is that this dictionary contains only core senses, many utterances which may appear well-formed to a human reader will be labelled as ill-formed.

Well-formedness almost coincides with literalness in this scheme, the difference being that literalness is a comment on actual speaker meaning – an utterance is literal if its *intended* meaning coincides with the core meanings of the words – whereas well-formedness applies to possible speaker meaning – an utterance is well-formed if it *could* be interpreted with the core meanings of the words. It can be seen that under these definitions, any literal utterance must also be well-formed, but the converse is not true. An example of a well-formed utterance intended non-literally would be any sentential metaphor; for example

- (1) *Mrs. Thatcher squashed Mr. Kinnock*

is well-formed (taking the core sense of squash to be physical squashing), but highly unlikely to be uttered literally.

It should be pointed out that well-formedness is to be decided *after* reference resolution, since judgement of semantic well-formedness relies on a knowledge of referents. This is especially clear when proper names are used, as there is insufficient semantic information in a name *per se*. Consider the example

- (2) *Washington is a city.*

² Well-formedness is applied to utterances, rather than sentences, as reference resolution must be done before it can be decided, as discussed shortly.

If 'Washington' is seen to refer to the man, then this utterance is ill-formed, but if 'Washington' refers to the capital of the United States, then the utterance is perfectly well-formed.

Having now established suitable notions of literalness and well-formedness, it is possible to go on to take a look at the sort of processing involved in producing a literal paraphrase of a manifestation of a systematic metaphor.

3.2 An informal look at processing

This section takes an informal look at the sort of processing which will be used to interpret systematic metaphor in the MINT system, but in a way which is independent of any particular representation scheme. This necessarily means a lack of rigour, but it gives a good idea of what metaphorical processing will look like, showing what the theory of descriptonal analogy is aiming for and motivating the use of analogy in this theory. Later sections will give a more formal treatment.

3.2.1 A case study

A suitable case for study is provided by Lakoff and Johnson's THE MIND IS A BRITTLE OBJECT, where a person, or their mind, is described as though they were a physical structure which can somehow be broken:³

- (3) *Her ego is very fragile*
- (4) *You have to handle him with care since his wife's death*
- (5) *He broke under cross-examination*
- (6) *The experience shattered him*
- (7) *I'm going to pieces*
- (8) *His mind snapped.*

Here it is assumed that the physical senses of 'fragile', 'break', 'shatter', and so on are their core senses, thus examples (3) – (8) are not literal.

The interpretation of these utterances, according to the theory of descriptonal analogy, relies on knowledge of the core analogy which underlies all manifestations of THE MIND IS A BRITTLE OBJECT. This analogy is expressed as a relationship between ideas in the domain of psychology and the domain of physical objects. Metaphorical interpretation is achieved by rephrasing a metaphorical utterance until it is expressed in terms which can be interpreted directly via the core analogy.

³ [Lakoff and Johnson 80] p. 28.

In the core analogy in this case, a person is seen as a physical structure, and the self assurance, or 'confidence' of that person is seen as the structural integrity of this structure.⁴ The explanation of this very simple analogy is as follows. Structural integrity can vary: a broken structure has a very low integrity, whereas one that is sound has a high integrity. Analogously, a 'broken' person has low 'confidence', whereas an 'unbroken' person has high confidence.

The steps involved in the interpretation of (6) can be shown symbolically as follows:

- *The experience shattered him*
- **The experience severely reduced his structural integrity*
- *→ *The experience severely reduced his confidence.*

where an asterisk (*) marks an utterance as non-literal, '→' indicates a rephrasing step, and '*→' indicates metaphorical interpretation via the core analogy.

There are several points to be made concerning this example. The original metaphorical utterance is marked as non-literal, but otherwise is taken at face value. The process of rephrasing is a sort of inference using the *core* senses of words ('shatter', for example, is taken as meaning 'severe reduction in structural integrity'). This rephrasing has the effect of rendering the original metaphorical utterance in terms which can be interpreted directly via the core analogy, as indicated in the last step of processing.

A similar treatment can be given to (5) and (3), as shown below.

- *He broke under cross-examination*
- *He broke due to cross-examination*
- **His structural integrity was severely reduced due to cross-examination*
- *→ *His confidence was severely reduced due to cross-examination.*

- *Her ego is very fragile*
- **Her ego is easily broken*
- **Her structural integrity is easily severely reduced*
- *→ *Her confidence is easily severely reduced.*

Using this approach, the required metaphorical senses for the words 'shatter', 'break', and 'fragile' are nowhere specified explicitly as polysemes, instead they are 'induced' by the single core analogy through its interaction with the core (physical) senses on a semantic level.

The analogy used so far has been very simple, involving only 'structural integrity' and 'confidence'. It can, however, be elaborated to give greater power to the metaphorical interpretation step. Take, for instance, the last of the above examples. The rather clumsy 'is easily broken' can be avoided by noting that a 'weak' structure is one that is easily damaged, whereas a 'strong' one is not easily damaged. The core analogy of mind as

⁴ 'Confidence' is not quite the right word, but it is an approximation – it is inevitable that approximations should be made when dealing with complex domains such as states of mind.

physical structure can be elaborated to include the idea that the 'strength-of-character' of the person is seen as the physical strength of the structure.⁵ This gives an alternative sequence of interpretation steps:

- **Her ego is very fragile*
- **Her ego is very weak*
- **The strength of her ego is very low*
- *→ *Her strength-of-character is very low.*

The depth of this systematic metaphor is further exemplified by introducing the idea of destructive forces acting upon the mind, as in the following examples:

- (9) *He crumbled under the pressure*
She just couldn't bear the strain
The tension was too much for him
He bore up well under stress.

It is clear that this systematic metaphor, THE MIND IS A BRITTLE OBJECT, is based on quite a strong parallelism between the domains of psychology and physical objects: physical structures can be strong or weak – if they are strong they are able to withstand pressures and strains without breaking; people can have 'strong' or 'weak' characters – if they are psychologically 'strong' they can withstand psychological 'pressures' and 'strains' without mentally 'breaking'.

This parallelism is more than a simple correspondence of words, but is a correspondence on the semantic level, it is a correspondence between the domains themselves; there is an *analogy* between the two domains, and this analogy characterizes the systematic metaphor THE MIND IS A BRITTLE OBJECT. The task of representing the systematic metaphor, then, amounts to representing the underlying core analogy, and the reasoning process used above to interpret manifestations of systematic metaphor is a form of analogical reasoning.

3.3 Analogy

Analogy and analogical reasoning have long been studied in the computing literature (see [Hall 89] for a survey). These studies have been attempts to make use of analogy in a number of areas of Artificial Intelligence, viz, theorem proving, planning and problem solving, and machine learning. The processing involved in these applications is generally very demanding, and so the techniques developed have generally been heuristic in nature. This short section is intended to outline the basic ideas and terminology of analogy, just sufficient to support the ensuing analogical treatment of metaphor.

⁵ 'Strength-of-character' has been hyphenated to show that it is a new word, with its core sense in the domain of psychology. This avoids any problem of circularity arising from the fact that it contains the word 'strength', whose core sense is presumed to be in the domain of physical objects.

An analogy is a special relationship that holds between two 'domains'. A 'domain' is generally regarded as a cluster of interrelated knowledge and facts, for example, Geometry might be said to be a domain, containing knowledge about points, lines, angles, proportionality, Pythagoras' theorem, and so on. Another domain might be International Politics, containing knowledge of world leaders, World War II, the Treaty of Versailles, summit meetings, and so on. A domain need not be so big, for instance The State Visit would be just as good a domain as International Politics, and so overlapping or completely contained domains are quite in order. As a rule, it is not easy to delineate domains with any precision, even within a formal subject such as mathematics. Consequently, the term 'domain' is meant to refer to a general subject area, without being a particularly formal notion.⁶

There is an 'analogy' between two domains if there are apparent parallels between some parts of them:⁷ for example, there is an analogy between the domains of the brain and the computer – the brain is analogous to the computer in that both take input signals, process them with reference to data stored in a memory, and produce output signals. An 'analogical mapping' is a formal description of how various ideas in the two domains of an analogy are related to each other (Figure 2).

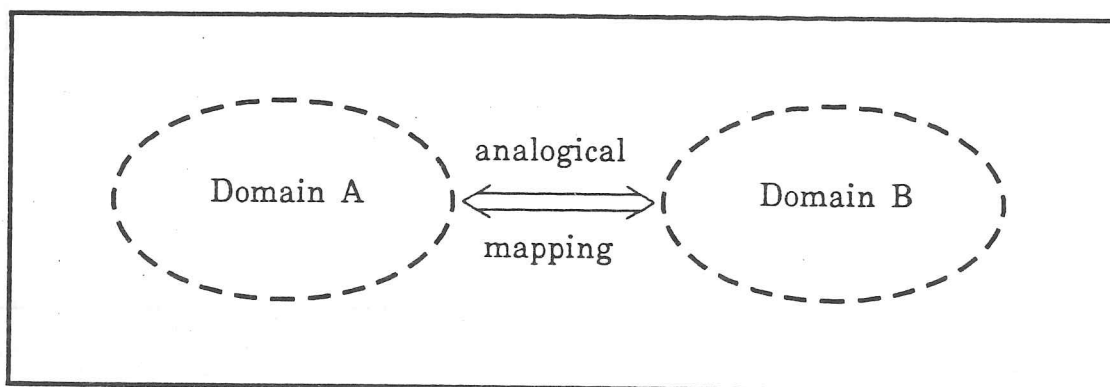


Figure 2: Analogy between two domains.

In the above brain-computer example, the analogical mapping would state that the brain corresponds to the computer, sensory input corresponds to the input data of the computer, the output nerve signals to the output data, the memory of the brain to the memory of the computer, and thinking in the brain to the processing of data in the computer.

⁶ Many computational treatments of analogy do have rather a strong idea of domain in their implementations, for example Indurkha's Constrained Semantic Transference already mentioned [Indurkha 85, 86, 87]; but authors generally agree that this is not a desirable state of affairs, as domains are so hard to delimit.

⁷ The two domains need not necessarily be distinct; indeed, because of the difficulty in defining domains, it would be hard to stipulate any useful conditions on them.

For convenience, an analogy is often said to exist 'between' the *ideas* mentioned in its analogical mapping, as well as between the *domains*. This ambiguity should not, however, lead to any confusion.

It is often the case that the analogy between two domains is asymmetric; one of the domains is better known, and the analogical relationship is set up in order that knowledge in the better known domain can be brought to bear on the lesser known domain. In these cases there is a 'flow of ideas' from one domain, the 'source domain', to the other, the 'target domain' (Figure 3).

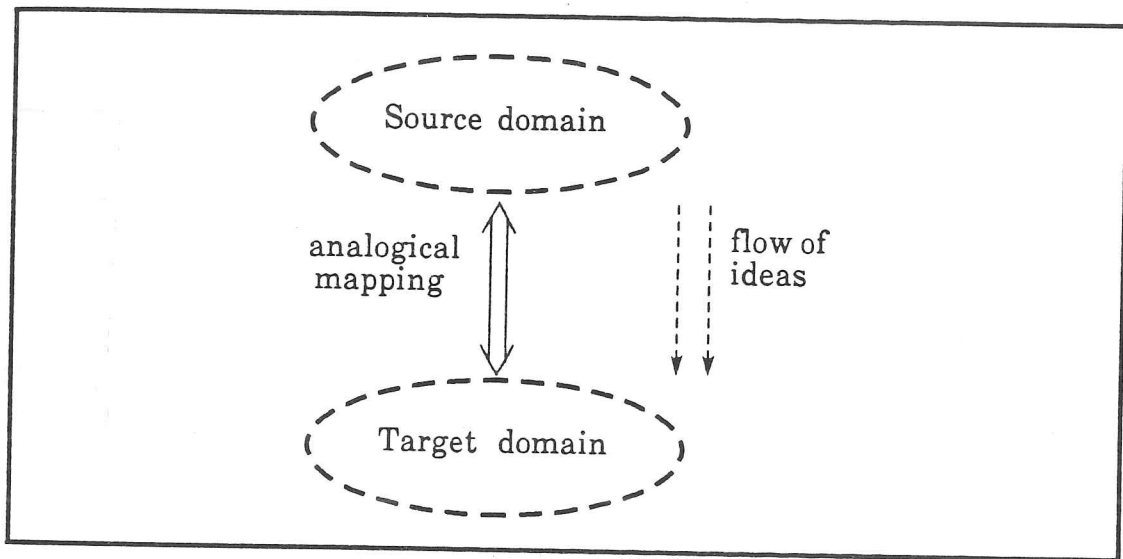


Figure 3: Flow of ideas in an analogy.

This flow of ideas is the basis for computational interest in analogy – if a suitable analogy can be found, a computer system might be able to use existing knowledge it has of the source domain and apply it in the target domain. In problem solving, for example, if a problem under investigation can be seen to be analogous to one that has been previously solved, then the previous solution strategy could be used to assist the solution of the new problem. In machine learning, where knowledge in a new domain has to be expanded and organized, an analogy with a better known domain, which might be given by a teacher or guessed at by the system, could be used to form conjectures or organize knowledge in the new domain.

'Analogical reasoning' is a form of reasoning that makes direct use of an analogy: To solve a problem in the target domain, the problem is mapped, via the analogical mapping, into a problem in the source domain. This source problem is then solved and the solution mapped back to a solution in the target domain (Figure 4).

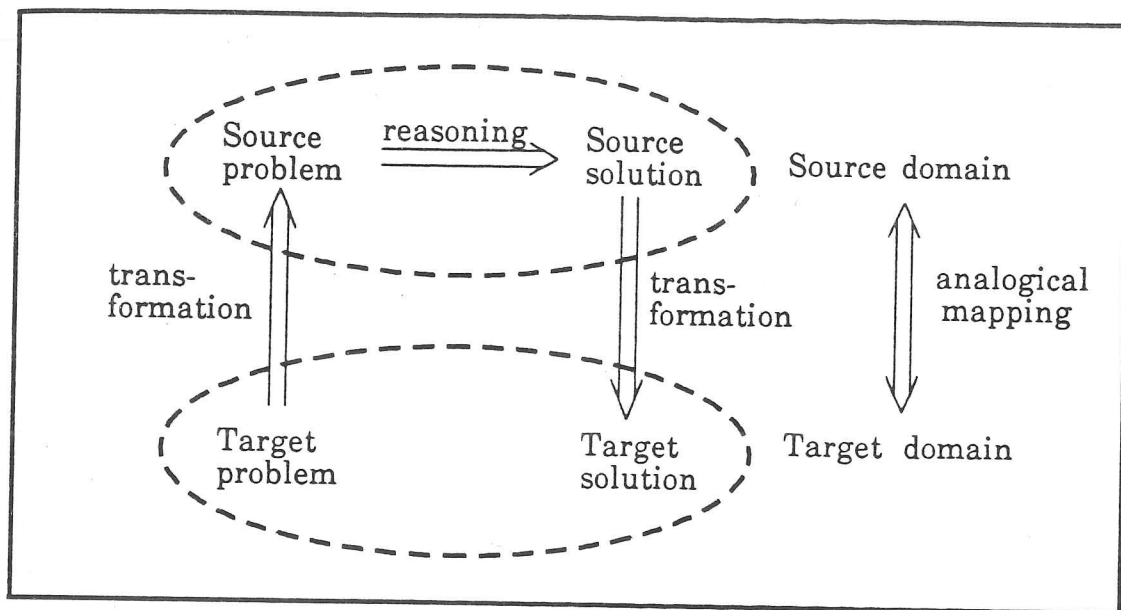


Figure 4: Analogical reasoning

This sort of reasoning is very common in mathematics, where a problem in an unfamiliar or difficult mathematical domain is transformed into a problem in a different domain, such as geometry or mechanics, where a method of solution might be more obvious or simply easier to calculate; a solution is then found and transformed back to a solution in the target domain.

A mathematician has to be very careful that this sort of analogical reasoning is indeed valid – the analogy has to be very good before results proved in the source domain can be assumed valid in the target domain. In general, and in particular when considering metaphor, it is not possible to prove the validity of analogical reasoning, and so results derived in this way must be treated with caution. This does not prevent analogical reasoning from being useful; it may be, for instance, that source reasoning can be used as a *guide* for target reasoning. It might, on the other hand, simply be the best one can do when there is insufficient knowledge of the target domain to allow any other sort of reasoning.

3.4 Descriptive Analogy

It is now possible to describe the theory of metaphor interpretation by analogical reasoning that is used in the MINT system. In the remainder of this chapter, the theory is described as it applies to metaphors considered in isolation, in the next, its application to systematic metaphor is presented.

3.4.1 The Principle of Descriptive Analogy

The relationship between metaphor and analogy in this theory can be summarized in the Principle of Descriptive Analogy:

A metaphor is the linguistic manifestation of an underlying analogy between its sources and targets. Moreover, given an analogy, any description of its sources can be applied metaphorically to the corresponding targets – a process called 'description inheritance'.

This principle gives a recipe for taking an analogy and deriving metaphorical descriptions of its targets. It is rather a strong statement that *any* description of the sources can be applied metaphorically to the targets, and in practice, many such descriptions will not be very useful; the important point is that they are not ruled out.

A further point to be made is that descriptions inherited by targets by this mechanism are in general assumed to be metaphorical, but it can happen that such a description is well-formed, in which case it may be 'accepted' as literal if this is thought appropriate. This leads to the interesting and important observation that not only metaphorical, but also 'literal' utterances may be seen as arising out of underlying analogies, and this is made much of in the theory of descriptive analogy detailed in the rest of this chapter – *all* utterances, both literal and metaphorical, are treated as evidencing analogies between discourse entities (the targets) and (usually) so-called 'definitive entities' (the sources). This uniform treatment of literal and metaphorical utterances is seen as one of descriptive analogy's chief advantages over other theories of metaphor interpretation.

The key point relating the principle to the informal account of metaphor interpretation given above is that descriptions of the sources can be arrived at by *inference* in the source domain, and can then be 'inherited' by the targets by virtue of the original analogy – this is a sort of analogical reasoning about descriptions. Figure 5 shows this descriptive analogical reasoning; 'target replacement' is the operation of substituting sources for the corresponding targets in a description (as defined by the analogical mapping) and 'source replacement' is the converse operation. Yet another point to notice is that there is nothing to prevent *metaphorical* descriptions of the sources being inherited by the targets – *all* descriptions are regarded as equally valid for this purpose, regardless of whether or not they are well-formed. These metaphorical descriptions of the sources will themselves have been derived from their own underlying analogy, so it is possible to build up chains of analogies and corresponding metaphorical description inheritance, a process that is used extensively below.

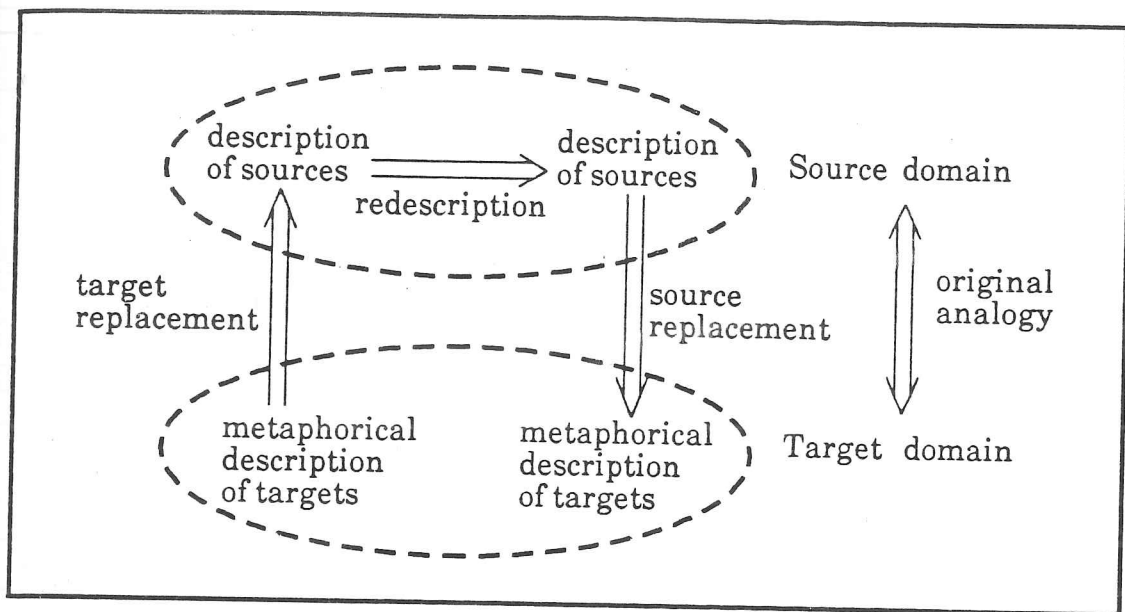


Figure 5: Descriptive analogical reasoning.

3.4.2 An overall view of processing

The principle of descriptive analogy can be put to work in the task of producing a literal paraphrase of an input utterance. This is not the only application of the theory, for example, metaphor production can be explained as depending on the perception of analogies, but it is the one chosen for the purposes of this thesis.

The rest of this chapter is devoted to a detailed discussion of the processes of descriptive analogy, building up to a practicable method for interpreting isolated metaphors. This is inevitably somewhat protracted, and so by way of a preview, a brief summary of this interpretation is offered here.

Processing can be divided into four stages:

- (1) The input utterance, whether literal or metaphorical, is used to construct an analogy whose targets correspond to the discourse entities of the utterance.
- (2) This analogy, in conjunction with the principle of descriptive analogy, is used to generate further metaphorical descriptions of the targets.
- (3) In the case of systematic and extended metaphor, these new descriptions are further interpreted with reference to previously known analogies.
- (4) Certain of these new descriptions of the targets are then 'accepted' to form part of a literal paraphrase.

3.5 C-entities, definitive entities, and intrinsic descriptions

3.5.1 C-entities and descriptions

A conclusion of chapter 2 was that the sources and targets of metaphors were c-entities, i.e., mental objects and not simply textual objects. It is therefore necessary to distinguish the c-entities in a sentence from descriptive terms which refer to them. In order to make this distinction, c-entities will be written as terms in angle brackets and descriptions will be written in italics. For example, in

- (10) $\langle \text{Fred} \rangle$ *is a policeman*

$\langle \text{Fred} \rangle$ is a c-entity, and 'is a policeman' is a description of that entity.

Where a c-entity does not have an obvious proper name, a suitable name may be invented for the purpose. For example, the c-entity which is the colour of a particular box might be called $\langle \text{colour31} \rangle$ and the box itself might be called $\langle \text{box31} \rangle$. These c-entities can be given descriptions in just the same way as $\langle \text{Fred} \rangle$ was. It is also possible to give groups of c-entities *relational* descriptions, for example

- (11) $\langle \text{colour31} \rangle$ *is the colour of* $\langle \text{box31} \rangle$,
(12) $\langle \text{Fred} \rangle$ *is married to* $\langle \text{Betty} \rangle$.

Non-literalness and ill-formedness

It can be seen that these combinations of c-entities and descriptions correspond closely to utterances after reference resolution. As such, they can be judged to be well-formed or ill-formed, and in the former case, literal or non-literal. In future, such resolved utterances will be labelled to make the distinction clear. Utterances, after reference resolution, which are judged ill-formed (and so inevitably non-literal) will be marked with a double dagger, as in⁸

- (13) $\dagger\dagger \langle \text{My wife} \rangle$ *is an angel*.

Utterances which are not intended literally, but which are nevertheless well-formed (that is, they *could* be interpreted literally) will be marked with a single dagger, for example⁹

- (14) $\dagger \langle \text{The professor} \rangle$ *eats people like him for breakfast*.

Literal utterances, which inevitably are also well-formed, will appear with no mark at all.

⁸ Recall that here literalness and well-formedness are judged with respect to *core* senses only. The core sense of 'angel' is taken to exclude earthly people.

⁹ This description is rather more complex than will be necessary in later examples, when the theory is more fully developed.

3.5.2 Definitive entities

Entities in descriptonal analogy

It has been emphasized before that the sources and targets of metaphors (and their underlying analogies) are c-entities. The targets of metaphors can generally be identified by reference resolution, but how to establish suitable c-entities to act as the sources is not so obvious. For instance, in the simplest example of a nominal metaphor,

(15) *John is a lion,*

⟨John⟩ can readily be identified as the target but the source would appear to be some arbitrary lion. One approach would be to invent a new lion, say ⟨lion31⟩, especially for the purpose, but this is a little unsatisfactory – it would seem to be creating a new discourse entity, i.e., a c-entity introduced, albeit implicitly, in the utterance, but one with an inferior status to ‘normal’ discourse entities. For example, if a discourse following on from (15) alluded to ‘the lion’, this would appear unambiguously to refer to ⟨John⟩, with no possibility of its referring to ⟨lion31⟩.

It is not, however, always necessary to invent a new source entity – a specific source may be given in a metaphor,¹⁰ as in the examples

(16) ††⟨Cold fusion⟩ *is the* ⟨Holy Grail⟩ *of* ⟨nuclear physics⟩

(17) ††⟨Oswald Moseley⟩ *was the* ⟨Adolf Hitler⟩ *of* ⟨pre-war Britain⟩.

It is possible to extend this idea of forming analogies with existing c-entities so as to avoid having to invent new source c-entities. The entities used in place of these invented entities are termed ‘definitive entities’ and their use lends great cohesion to the whole process of descriptonal analogy – the use of definitive entities is the key to the uniformity of processing literal and metaphorical utterances, and also the determination of underlying analogies from input metaphors.

Definitive entities

Consider the concept of a man. There might be any number of known men, say ⟨Ronald Reagan⟩, ⟨Henry VIII⟩, ⟨Biggles⟩, ⟨Bruce Wayne⟩, and ⟨John⟩, but it is possible to imagine, in addition, an archetypal man, the *definitive* example of a man, an entity with just the essential properties of a man. This man does not actually exist outside the mind, but is nevertheless a perfectly good c-entity, and will be known as the ‘definitive entity’ ⟨man⟩.

¹⁰ This accords well with the technique in analogical reasoning of forming analogies with known examples in order to solve problems concerning new examples.

Similar definitive entities can be imagined corresponding to the archetypal lion, ogre, colour, piece of music, emotion, marriage, mathematical theorem, and so on. Even very abstract definitive entities, such as \langle wet-stuff \rangle (the archetypal stuff that is wet) are quite in order.

These definitive entities can have properties associated with them, and in particular they are fundamentally associated with their most basic descriptions. For example, among all men, \langle man \rangle is the best described as 'a man', \langle ogre \rangle , the definitive ogre, as 'an ogre', and so on. For a given definitive entity, descriptions that are fundamentally associated with it in this way will be termed 'intrinsic descriptions' of that entity, conversely, the intrinsic descriptions will be said to 'belong' to that entity. Some examples of definitive entities and intrinsic descriptions are

- (18) \langle man \rangle *is a man*
- (19) \langle ogre \rangle *is an ogre*
- (20) \langle red \rangle *is red*
- (21) \langle water \rangle *is water*
- (22) \langle wet-stuff \rangle *is wet*
- (23) \langle unpleasant-thing \rangle *is unpleasant*

It has been emphasized repeatedly that *relationships* between c-entities are of great importance. Accordingly, definitive entities can be involved in 'definitive relationships', for example the definitive entity \langle mother \rangle is intimately related to the definitive entity \langle child \rangle , and in particular there are intrinsic descriptions of this relationship:

- (24) \langle mother \rangle *is the mother of* \langle child \rangle
- (25) \langle mother \rangle *is* \langle child \rangle 's *mother*

and the description 'is the mother of' can be said to belong jointly to these two entities.

These definitive entities provide a natural way to reason with descriptions: because descriptions are seen as belonging to definitive entities, the processes of descriptonal analogy can be transformed from a rather ill-defined reasoning with words to a much more concrete reasoning about entities. This reasoning process is described below.

3.6 Description inheritance from definitive entities

Definitive entities, like any other c-entities, can enter into analogical relationships. These analogies, in conjunction with the principle, explain how descriptions come to be applied to more than one entity.

3.6.1 Simple description inheritance

Consider the definitive entity $\langle \text{dog} \rangle$, the archetypal dog. There is an obvious analogy between any c-entity normally called 'a dog' and $\langle \text{dog} \rangle$, so, according to the principle, these entities can inherit $\langle \text{dog} \rangle$'s intrinsic descriptions. For example, suppose that $\langle \text{Fido} \rangle$ is indeed a dog, then the obvious analogy explains how the description 'is a dog' (which belongs to $\langle \text{dog} \rangle$) comes to be applied to $\langle \text{Fido} \rangle$. This description inheritance can be written symbolically as follows:

$$\begin{array}{l} [\langle \text{Fido} \rangle \text{ is-analogous-to } \langle \text{dog} \rangle] \\ \quad \langle \text{dog} \rangle \text{ is a dog} \\ \Downarrow \quad \dagger \langle \text{Fido} \rangle \text{ is a dog.} \end{array}$$

This notation requires some explanation. The analogy between $\langle \text{Fido} \rangle$ and $\langle \text{dog} \rangle$ is represented on the first line, where 'is-analogous-to' is a relation between two c-entities, the first being the target and the second being the source. The first line of description, consisting of $\langle \text{dog} \rangle$ and (one of) its intrinsic descriptions, is taken to be freely available as a sort of axiom. The final line is the result of 'source replacement', an operation whereby a source of an analogy is replaced by the corresponding target (in this simple case there is only one of each). Source replacement is represented by ' \Downarrow ' (this notation is deliberately chosen to match that used in figure 5).

In accordance with the principle of descriptonal analogy, this description of $\langle \text{Fido} \rangle$ is marked (by the dagger) as being well-formed, but metaphorical. This metaphorical labelling is really erring on the side of caution, but the analogy in this example is a very good one, and since the final description does not conflict with existing knowledge about $\langle \text{Fido} \rangle$, it can be 'accepted' (by some as yet unspecified mechanism) as literal, and this is indicated by underlining. The notion of acceptance plays an important part in the interpretation of metaphors, and more will be said about it in due course.

3.6.2 Chaining analogies

Now, $\langle \text{dog} \rangle$ itself can be the target of further analogical relationships, and can inherit descriptions as a result, for example, there is an analogy between $\langle \text{dog} \rangle$ and $\langle \text{animal} \rangle$ the definitive animal:

$$\begin{array}{l} [\langle \text{dog} \rangle \text{ is-analogous-to } \langle \text{animal} \rangle] \\ \quad \langle \text{animal} \rangle \text{ is an animal} \\ \Downarrow \quad \dagger \langle \text{dog} \rangle \text{ is an animal,} \end{array}$$

and this description of $\langle \text{dog} \rangle$ can be inherited by $\langle \text{Fido} \rangle$ by *chaining* the analogies:

- 1: [*<Fido>* is-analogous-to *<dog>*]
 - 2: [*<dog>* is-analogous-to *<animal>*]
- <animal>* is an animal
- \Downarrow_2 †*<dog>* is an animal
- \Downarrow_1 †*<Fido>* is an animal,

where the subscripts indicate which of the two separate analogies is being used. There is no limit to the length of such chains of description inheritance, and so the existence of further analogies involving yet more definitive entities allows numerous descriptions to be inherited by *<Fido>*.

This chaining of analogies is illustrated diagrammatically in figure 6. The operations of target replacement and redescription will be discussed later.

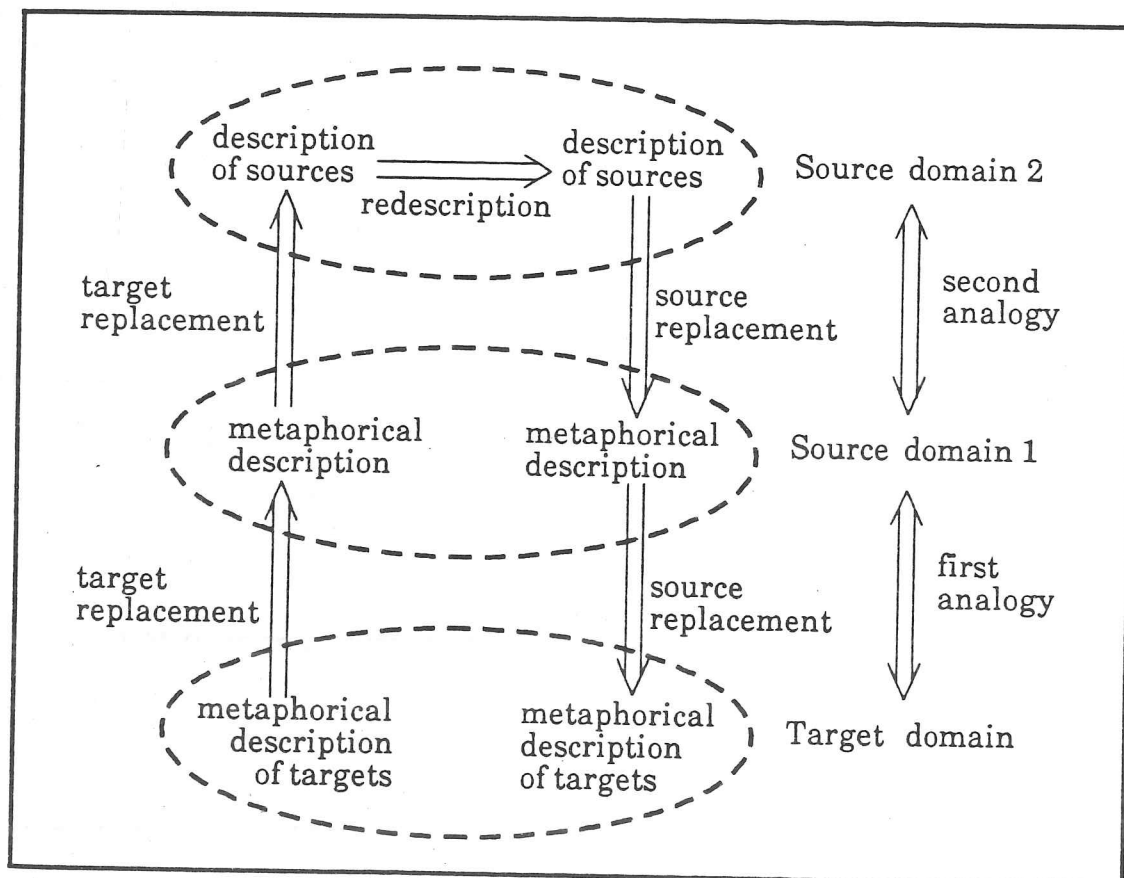


Figure 6: Chaining of analogies

3.6.3 Relational description inheritance

The same principles can be applied to the inheritance of relational descriptions. Just as all dogs were seen to be analogous to *<dog>*, all mothers are analogous to *<mother>* and all children to *<child>*. If an analogy should specify two such correspondences *together*, then descriptions of the *relationship* between *<mother>* and *<child>* can be inherited by the two

targets. For example, suppose that $\langle \text{Mary} \rangle$ and $\langle \text{Dick} \rangle$ are related as mother and child, then there is an obvious analogy between $\langle \text{Mary} \rangle$, $\langle \text{Dick} \rangle$, $\langle \text{mother} \rangle$, and $\langle \text{child} \rangle$ in which the former two c-entities are targets and the latter two are the corresponding sources. Relational description inheritance works as follows:

[$\langle \text{Mary} \rangle$ is-analogous-to $\langle \text{mother} \rangle$
and $\langle \text{Dick} \rangle$ is-analogous-to $\langle \text{child} \rangle$]
 \Downarrow $\langle \text{mother} \rangle$ is $\langle \text{child} \rangle$'s mother.
 \Downarrow $\dagger \langle \text{Mary} \rangle$ is $\langle \text{Dick} \rangle$'s mother.

Notice that this relational description inheritance will only work if both mother and child are specified in the *same* analogy, because otherwise the source replacement step would fail. This is as it should be, it would be a mistake to describe $\langle x \rangle$ as the mother of $\langle y \rangle$ if $\langle x \rangle$ were a mother and $\langle y \rangle$ a child, but in different families.

As before, it is possible to chain analogies to obtain further descriptions, both simple and relational:

1: [$\langle \text{Mary} \rangle$ is-analogous-to $\langle \text{mother} \rangle$
and $\langle \text{Dick} \rangle$ is-analogous-to $\langle \text{child} \rangle$]
2: [$\langle \text{mother} \rangle$ is-analogous-to $\langle \text{woman} \rangle$]
 \Downarrow_2 $\langle \text{woman} \rangle$ is a woman
 \Downarrow_1 $\dagger \langle \text{mother} \rangle$ is a woman
 \Downarrow_1 $\dagger \langle \text{Mary} \rangle$ is a woman,

similarly,

1: [$\langle \text{Mary} \rangle$ is-analogous-to $\langle \text{mother} \rangle$
and $\langle \text{Dick} \rangle$ is-analogous-to $\langle \text{child} \rangle$]
2: [$\langle \text{mother} \rangle$ is-analogous-to $\langle \text{ancestor} \rangle$
and $\langle \text{child} \rangle$ is-analogous-to $\langle \text{descendent} \rangle$]
 \Downarrow_2 $\langle \text{ancestor} \rangle$ is an ancestor of $\langle \text{descendent} \rangle$
 \Downarrow_1 $\dagger \langle \text{mother} \rangle$ is an ancestor of $\langle \text{child} \rangle$
 \Downarrow_1 $\dagger \langle \text{Mary} \rangle$ is an ancestor of $\langle \text{Dick} \rangle$

3.6.4 Predicative descriptions

The same relational idiom can account for predicative descriptions. Take, for example, the situation of interviewing. The definitive interview can be considered to be a relationship between two definitive entities, $\langle \text{interviewer} \rangle$ and $\langle \text{interviewee} \rangle$.¹¹ Other interviews can be regarded as analogous to this definitive interview, and so can inherit relational descriptions:

[$\langle \text{Tom} \rangle$ is-analogous-to $\langle \text{interviewer} \rangle$
and $\langle \text{Harry} \rangle$ is-analogous-to $\langle \text{interviewee} \rangle$]
 \Downarrow $\langle \text{interviewer} \rangle$ interviews $\langle \text{interviewee} \rangle$
 \Downarrow $\dagger \langle \text{Tom} \rangle$ interviews $\langle \text{Harry} \rangle$,

¹¹ Later it will be found useful to add a third definitive entity into this relationship – the definitive interviewing event.

and further descriptions can again be inherited by chaining.

3.7 Analogies and knowledge

In the above discussion of description inheritance from definitive entities the rôle of analogies was paramount. The analogies used were very obvious, indeed one would be tempted to say that 'is-a' would be as appropriate in those examples as 'is-analogous-to', but definitive entities are intensional individuals and so saying that $\langle \text{John} \rangle$ is-a $\langle \text{man} \rangle$ would be like saying that $\langle \text{John} \rangle$ is-a $\langle \text{Fred} \rangle$.¹²

These 'obvious' analogies simply correspond to 'commonsense' knowledge, and this is why they are freely available for the purposes of description inheritance. For instance, that $\langle \text{dog} \rangle$ is-analogous-to $\langle \text{animal} \rangle$ simply codes the knowledge that dogs are animals. Similarly, analogies code the knowledge that mothers are ancestors and Mary is a mother, even though the latter is contingent, rather than commonsense, knowledge. During the processes of descriptonal analogy three types of knowledge are used: (a) commonsense knowledge, which is coded as 'background analogies' between definitive entities, (b) contingent knowledge, which is usually coded as 'input analogies' between discourse entities and definitive entities, and (c) intrinsic descriptonal knowledge, which simply takes the form of basic descriptions belonging to definitive entities.¹³ There is no difference in form between the first two types of knowledge, since discourse and definitive entities are all just c-entities and handled in exactly the same way using exactly the same mechanisms. Indeed, as will be seen later, the two types of analogy are stored identically in the semantic network used by MINT.

Dictionary definitions

It should be appreciated that dictionary definitions fall into the first category of knowledge, for example, if 'dog' is defined as 'a carnivorous animal', this definition is reflected in the existence of background analogies between $\langle \text{dog} \rangle$, $\langle \text{animal} \rangle$, and $\langle \text{carnivore} \rangle$. The link between the *words* and the analogies is made by the anchoring of intrinsic descriptions to definitive entities. Much more complex definitions can be accommodated through the use of more, and more complex background analogies.

¹² Of course, the English version of this does crop up in metaphors, for example "Moseley is another Hitler".

¹³ Knowledge about well-formedness conditions is handled separately – well-formedness has no effect at all on the mechanisms of descriptonal analogy, it is only relevant to the issue of acceptance, which is an external process. Descriptonal analogy in itself regards all descriptions as metaphorical, unless they are intrinsic descriptions being applied to their definitive entities.

3.8 Determining underlying analogies

Definitive entities, then, are used to define the *origins* of descriptions in the system of descriptonal analogy, and the fact that more than one entity can be described in the same way is put down to the extensive analogical interrelationships between them. But the idea that descriptions belong in some fundamental sense to particular entities or combinations of entities can also be used to explain *how* the input analogies (i.e., the *underlying* analogies) used in processing metaphors are determined from input utterances.

Consider the utterance

(26) *Bonzo is a dog.*

This utterance contains explicit reference to the entity ⟨Bonzo⟩, but also an implicit reference to the definitive entity ⟨dog⟩, as the word 'dog' is fundamentally associated with ⟨dog⟩. The very fact that ⟨Bonzo⟩ is being described in terms which belong to ⟨dog⟩ indicates an analogical relationship between the two.¹⁴ Using this reasoning, initial processing of (26) yields the input analogy

[⟨Bonzo⟩ is-analogous-to ⟨dog⟩]

Having established this analogy, other descriptions of ⟨Bonzo⟩ can be inherited directly from ⟨dog⟩, or indirectly via other analogies which have ⟨dog⟩ as a target, and this is the basic mechanism of paraphrase, which is discussed more fully later.

Note that if the input utterance had been the metaphor

(27) *John is a dog*

a very similar input analogy (with ⟨John⟩ substituted for ⟨Bonzo⟩) would have resulted.

A similar analysis can be given for relational descriptions. For example

(28) *Fred interviewed Mary*

would be interpreted as

[⟨Fred⟩ is-analogous-to ⟨interviewer⟩
and ⟨Mary⟩ is-analogous-to ⟨interviewee⟩]

whereupon other descriptions of the relationship between ⟨Fred⟩ and ⟨Mary⟩ could be generated and accepted.

In general, simple English descriptions can be transformed into input analogies by a sort of look-up process: targets are determined by reference resolution, sources and the exact form

¹⁴ This assumes that the description of ⟨Bonzo⟩ is down to descriptonal analogy. It is possible that the description might have arisen in some other way, most notably by *metonymy*, which would indicate a different relationship between ⟨Bonzo⟩ and ⟨dog⟩. For the purposes of this investigation, however, analogy is assumed.

of the analogy are determined by the description itself. More complex descriptions can be transformed into a set of analogies by a compositional process driven by a syntactic parse of the input utterance. For example, the input utterance

(29) *Mary's mother interviewed John's mother*

would be decomposed into three input analogies sharing some of their targets as follows:

[⟨mother31⟩ is-analogous-to ⟨interviewer⟩
and ⟨mother32⟩ is-analogous-to ⟨interviewee⟩]

[⟨mother31⟩ is-analogous-to ⟨mother⟩
and ⟨Mary⟩ is-analogous-to ⟨child⟩]

[⟨mother32⟩ is-analogous-to ⟨mother⟩
and ⟨John⟩ is-analogous-to ⟨child⟩.]

There is no great need at this stage to make detailed commitments about this process of determining input analogies from utterances, as it is of practical, rather than theoretical concern. Of course, such a mechanism has been implemented in the MINT system, and this is described in a later chapter.

3.9 Descriptive analogy and isolated metaphors

Description inheritance and the mechanism for determining the input analogies for utterances provide the necessary equipment for metaphor interpretation. Before showing how this equipment can be applied to systematic metaphor, its application is described in the simpler case where metaphors are considered in isolation. This is done for nominal, predicative, and sentential metaphors. In each case it will be shown how the underlying analogy can be used to explain how the metaphor is derived and also to produce further (metaphorical) descriptions of its targets, a selection of which can be 'accepted' to form a literal paraphrase.

Nominal metaphors

Consider a simple example of nominal metaphor,

(30) *John is an ogre.*

According to the Principle of Descriptive Analogy, this metaphor is the linguistic manifestation of an analogy between ⟨John⟩ and the definitive ogre ⟨ogre⟩. This analogy can be derived from (30), by the mechanism described above. It is

(31) [⟨John⟩ is-analogous-to ⟨ogre⟩]

Conversely, given this analogy the principle shows how (30) is derived, shown symbolically as follows:

$$\begin{array}{l} \uparrow \uparrow \\ \Rightarrow \\ \downarrow \end{array} \begin{array}{l} \langle \text{John} \rangle \\ \langle \text{ogre} \rangle \\ \langle \text{ogre} \rangle \text{ is an ogre} \\ \uparrow \uparrow \langle \text{John} \rangle \text{ is an ogre} \end{array}$$

Notice that two new operations have been introduced here. They are intended to show a more directed form of description inheritance than the somewhat random inheritance from definitive entities described above. Here, as before, each line represents a description of the c-entities $\langle \text{John} \rangle$ or $\langle \text{ogre} \rangle$ (the first two lines represent the 'trivial', or 'null', description), ' $\uparrow \uparrow$ ' indicates target replacement ($\langle \text{ogre} \rangle$ for $\langle \text{John} \rangle$), ' \Rightarrow ' indicates redescription, and ' \downarrow ' indicates source replacement ($\langle \text{John} \rangle$ for $\langle \text{ogre} \rangle$). This notation has been chosen to match that used in figure 5.

Using the same input analogy in conjunction with previously known background analogies, $\langle \text{John} \rangle$ can be described using other terms applicable to $\langle \text{ogre} \rangle$, such as

- (32) $\uparrow \uparrow \langle \text{John} \rangle$ is a monster
- (33) $\uparrow \uparrow \langle \text{John} \rangle$ is a creature
- (34) $\uparrow \uparrow \langle \text{John} \rangle$ is a beast.

The symbolic derivation of the first of these is

$$\begin{array}{l} 1: \quad [\langle \text{John} \rangle \text{ is-analogous-to } \langle \text{ogre} \rangle] \\ 2: \quad [\langle \text{ogre} \rangle \text{ is-analogous-to } \langle \text{monster} \rangle] \\ \uparrow \uparrow_1 \quad \langle \text{John} \rangle \\ \uparrow \uparrow_2 \quad \langle \text{ogre} \rangle \\ \Rightarrow \quad \langle \text{monster} \rangle \text{ is a monster} \\ \downarrow \downarrow_2 \quad \uparrow \langle \text{ogre} \rangle \text{ is a monster} \\ \downarrow \downarrow_1 \quad \uparrow \uparrow \langle \text{John} \rangle \text{ is a monster.} \end{array}$$

Similar derivations can be given for the other two descriptions.

These descriptions of $\langle \text{John} \rangle$ remain metaphorical, and indeed ill-formed (assuming the core senses of 'monster', 'creature', and 'beast' require non-human referents). This does not, however, prevent them from being useful, particularly in future reference resolution, which is discussed later.

It is not inevitable that descriptions of the source should be ill-formed when applied to the target, for example, further reasoning in the source domain (searching for further background analogies) gives

- 1: [⟨John⟩ is-analogous-to ⟨ogre⟩]
 2: [⟨ogre⟩ is-analogous-to ⟨thing⟩]
 ⟨John⟩
 \Uparrow_1 ⟨ogre⟩
 \Uparrow_2 ⟨thing⟩
 \Rightarrow ⟨thing⟩ *is a thing*
 \Downarrow_2 †⟨ogre⟩ *is a thing*
 \Downarrow_1 †⟨John⟩ is a thing.

Also,

- 1: [⟨John⟩ is-analogous-to ⟨ogre⟩]
 2: [⟨ogre⟩ is-analogous-to ⟨frightening-thing⟩]
 ⟨John⟩
 \Uparrow_1 ⟨ogre⟩
 \Uparrow_2 ⟨frightening-thing⟩
 \Rightarrow ⟨frightening-thing⟩ *is frightening*
 \Downarrow_2 †⟨ogre⟩ *is frightening*
 \Downarrow_1 †⟨John⟩ is frightening.

These descriptions of ⟨John⟩ are well-formed, but still regarded as metaphorical according to the principle of descriptonal analogy. Because they are well-formed, however, they can be 'accepted' by some external mechanism as literal statements about ⟨John⟩ and used in the production of a literal paraphrase. This acceptance is indicated by the underlining. More will be said about acceptance later.

The power of the analogical view of metaphor becomes more evident for more complex metaphors where *relationships* are involved. For example, consider the nominal metaphor

- (35) *Inflation is a disease of the economy.*

This example can be seen as a manifestation of an analogy between ⟨inflation⟩ and ⟨disease⟩, and so description inheritance can be used to derive a number of further metaphorical descriptions of ⟨inflation⟩:

- (36) ††⟨inflation⟩ *can be painful*
 (37) ††⟨inflation⟩ *can be infectious*

some of them well-formed, such as

- (38) †⟨inflation⟩ is undesirable.

In addition, however, there are a number of *relational* inferences to be made in the source domain, such as

- (39) *A disease is damaging to the affected part*

which can be interpreted via the original input analogy to the well-formed statement¹⁵

- (40) †⟨inflation⟩ is damaging to ⟨the economy⟩.

¹⁵ Assuming that 'damage' is being used in its core sense in (40).

Symbolically, this is written

- 1: [(inflation) is-analogous-to (disease)
and (economy) is-analogous-to (affected-part)]
 - 2: [(disease) is-analogous-to (damaging-thing)
and (affected-part) is-analogous-to (damaged-thing)]
- \Uparrow_1 (inflation), (economy31)
 \Uparrow_1 (disease), (affected-part)
 \Uparrow_2 (damaging-thing), (damaged-thing)
 \Rightarrow (damaging-thing) is *damaging to* (damaged-thing)
 \Downarrow_2 †(disease) is *damaging to* (affected-part)
 \Downarrow_1 †(inflation) is *damaging to* (economy31).

This metaphorical interpretation of relationships is possible because the analogy underlying the original metaphor has *two* targets, viz (inflation) and (economy), and both of these are available to the interpretation process.

Predicative metaphors

Descriptive analogy works just as well for predicative metaphors, the difference being in the exact nature of the source and target entities. Consider the famous example

- (41) *The ship ploughs through the sea.*

The source of this metaphor is ploughing, but the target is unstated – it is simply whatever the ship was doing. Miller's interpretation of (41), [Miller 79], would have been

- (42) *The ship is doing something to the sea like something ploughing through something.*

This is no problem, however, for descriptive analogy, as it is easily circumvented by inventing a name for the first something, and noting that the second and third somethings are definitive entities of ploughing. Call them activity31, plough-ag, and plough-pat respectively. In addition, it will be useful to involve another definitive c-entity, (ploughing), for the ploughing of (plough-ag) through (plough-pat). It should be borne in mind that (plough-ag), (plough-pat), and (ploughing) are not simply ad hoc entities, they are bound to be available to processing, together with analogies involving them, since they are intimately connected with *knowledge* about ploughing – if such knowledge is at our disposal, then this is manifested in the existence of definitive entities along with background analogies expressing that knowledge.

The input analogy underlying (41) is determined, then, as one with three sources and targets (equivalent to a nominal metaphor with three targets):

- (43) [(ship31) is-analogous-to (plough-ag)
and (sea31) is-analogous-to (plough-pat)
and (activity31) is-analogous-to (ploughing)]

Thus the predicative metaphor is potentially productive of relational inferences. For example, descriptonal analogy yields

- (44) †⟨activity31⟩ *is the moving of* ⟨ship31⟩ *across* ⟨sea31⟩
 (45) †⟨activity31⟩ *is the pushing aside of* ⟨sea31⟩ *by* ⟨ship31⟩

or alternatively

- (46) †⟨ship31⟩ *is moving across* ⟨sea31⟩
 (47) †⟨ship31⟩ *is pushing aside* ⟨sea31⟩

both of which are well-formed and can be accepted. Symbolically, these descriptions are derived as follows:¹⁶

- ↑↑ ⟨activity31⟩, ⟨ship31⟩, ⟨sea31⟩
 ⟨ploughing⟩, ⟨plough-ag⟩, ⟨plough-pat⟩
 ⇒ a) ⟨ploughing⟩ *is the ploughing of* ⟨plough-ag⟩ *through* ⟨plough-pat⟩
 b) ⟨ploughing⟩ *is the moving of* ⟨plough-ag⟩ *across* ⟨plough-pat⟩
 c) ⟨ploughing⟩ *is the pushing aside of* ⟨plough-pat⟩ *by* ⟨plough-ag⟩
 ↓↓ ††a) ⟨activity31⟩ *is the ploughing of* ⟨ship31⟩ *through* ⟨sea31⟩
 †b) ⟨activity31⟩ *is the moving of* ⟨ship31⟩ *across* ⟨sea31⟩
 †c) ⟨activity31⟩ *is the pushing aside of* ⟨sea31⟩ *by* ⟨ship31⟩.

where (a), (b), and (c) represent alternative descriptions of the relevant entities.

Note that the inclusion of ⟨ploughing⟩ and ⟨activity31⟩ is not strictly necessary, it simply proves useful (especially in more complex examples) to have entities corresponding to the event or activity being described.

Sentential metaphors

Sentential metaphors can be characterized as utterances which are well-formed, but not literal. Consider the example (after reference resolution),

- (48) †⟨Mrs. Thatcher⟩ *was* ⟨Reagan⟩'s *slave*.

This is perfectly well-formed, but the literal interpretation of (48) is only one of a number, and it may be rejected on pragmatic grounds, in this case due to its unlikelihood.

If it is rejected, it is necessary to seek an alternative interpretation. One way of finding such an alternative would be to assume that the utterance was intended metaphorically, in which case descriptonal analogy can offer well-formed redescriptions such as

- (49) †⟨Mrs. Thatcher⟩ *did whatever* ⟨Reagan⟩ *told her to do*
 (50) †⟨Mrs. Thatcher⟩ *was dominated by* ⟨Reagan⟩
 (51) †⟨Reagan⟩ *controlled* ⟨Mrs. Thatcher⟩,

¹⁶ For simplicity, the analogies between ⟨ploughing⟩ *etc.* and ⟨moving⟩ and ⟨pushing⟩ have been omitted. These derivations are, however, no more complicated than that for 'damaging' presented above.

and so on.

Later it will be seen how choosing between systematic metaphors can also lead to alternative interpretations.

3.10 Another look at processing

The mechanisms given above are now sufficient to give a simple strategy for producing a literal paraphrase from an input metaphor (nominal, predicative, or sentential).

The strategy is as follows: (a) determine the underlying input analogy of the input metaphor, (b) use knowledge of background analogies to generate further descriptions of the targets, and (c) accept any of these descriptions that are well formed.¹⁷

It can be seen that this is an *abstraction* approach to metaphor interpretation: description inheritance corresponds to the property inheritance of, say, the interaction theories, and only well-formed (semantically compatible) descriptions (properties) of the sources are inherited by the targets to appear in the literal paraphrase. So, for example, the literal paraphrase of (30), (35), (41), and (48) would be made up of a set of descriptions inherited from the relevant sources, including

- (52) *John is frightening,*
John is a thing.
- (53) *Inflation is undesirable,*
Inflation is damaging to the economy.
- (54) *The ship moves across the sea,*
The ship pushes the sea aside.
- (55) *Reagan controlled Mrs. Thatcher.*

A point worth emphasizing is that because of the use of definitive entities, both literal and metaphorical utterances are transformed to analogies in the input process. Also, in the redescription process, no account is taken of whether descriptions are well- or ill-formed – it is only in determining which descriptions to include in a literal paraphrase that well-formedness is considered. Well-formedness has been taken to be a dictionary-dependent judgement, and so largely a matter of taste on the part of a lexicographer. The processing of both literal and metaphorical input, then, is very uniform in descriptonal analogy, very much in line with the observations made in chapter 2.

Already, there is a substantial improvement on the interaction theories discussed in chapter 2, as in descriptonal analogy it is possible to handle relationships, and literal and metaphorical processing proceed using the same mechanisms (the literal paraphrase of a

¹⁷ Well-formedness is actually only the initial filter for removing unwanted descriptions.

literal input would include that input, since it would be an inherited description that was found to be well-formed). But so far, metaphors have been considered only in isolation, that is, without reference to previously encountered metaphors or systematic metaphors. This was seen in chapter 2 to be a major failing of the abstraction approach, but in descriptive analogy, because of the emphasis on *descriptions*, rather than properties, this failing is easily overcome. The mechanism used is metaphorical reference resolution. This is the subject of the next chapter.

4. Descriptive Analogy and Systematic Metaphor

In the last chapter it was seen how the simple mechanism of description inheritance via analogies can explain how metaphors are generated and also how metaphors can be interpreted by abstraction. This chapter concludes the presentation of the theory of descriptive analogy by showing how it can be used to interpret extended metaphors and manifestations of systematic metaphor.

Overview

4.1 considers the basic process of reference resolution in which c-entities are identified from their descriptions. This process is extended naturally to allow reference resolution starting from metaphorical descriptions in extended metaphors. 4.2 shows how simple manifestations of systematic metaphor can be interpreted using the same process of metaphorical reference resolution. 4.3 extends the process to 'generalized' metaphorical reference resolution which enables the interpretation of much more complex manifestations of 'associated' systematic metaphors. 4.4 concludes the chapter with a discussion of the case when an input admits more than one interpretation.

4.1 Reference resolution

Consider the discourse fragment

- (1) *Rover is a dog. John is terrified of the animal.*

The second sentence in this example requires for its interpretation the identification of the referent of 'the animal'. This is done straightforwardly by noticing that the required reference resolution is simply a search for a known entity which can be described as 'an animal'. Such a description is found to apply to <Rover> by the following reasoning: as before, the first sentence is interpreted as expressing an analogy between <Rover> and <dog>:

[<Rover> is-analogous-to <dog>]

As a result of this analogy <Rover> inherits descriptions from <dog>, including (by chaining) that of being 'an animal':

1: [(Rover) is-analogous-to (dog)]
 2: [(dog) is-analogous-to (animal)]
 (Rover)
 $\uparrow\uparrow_1$ (dog)
 $\uparrow\uparrow_2$ (animal)
 \Rightarrow (animal) *is an animal*
 $\downarrow\downarrow_2$ †(dog) *is an animal*
 $\downarrow\downarrow_1$ †(Rover) *is an animal.*

Then, when processing the second sentence, 'the animal' can be resolved to (Rover), since (Rover) is an entity known to be describable as 'an animal':

John is terrified of the animal
 () (John) *is terrified of (Rover),*

where () indicates reference resolution. The description '(Rover) *is an animal*' is known as the 'antecedent description' for this resolution.

Having resolved the referent, further processing can be performed on the result.

Metaphorical reference resolution

Consider now the discourse fragment (which is an extended metaphor)

(2) *John is an ogre. The monster terrorizes the local children.*

The reference resolution in this example proceeds in just the same manner as before, the only difference being that the descriptions involved are marked as metaphorical. The antecedent description of (John) in this case can be derived from the first sentence as follows:

1: [(John) is-analogous-to (ogre)]
 2: [(ogre) is-analogous-to (monster)]
 (John)
 $\uparrow\uparrow_1$ (ogre)
 $\uparrow\uparrow_2$ (monster)
 \Rightarrow (monster) *is a monster*
 $\downarrow\downarrow_2$ †(ogre) *is a monster*
 $\downarrow\downarrow_1$ ††(John) *is a monster.*

The resolution step can be shown symbolically as follows:

The monster terrorizes the local children
 (†) (John) terrorizes the local children,

where '(†)' indicates that the reference resolution had a metaphorical antecedent description.

More generally, if an utterance is metaphorical, the principle of descriptonal analogy gives a way of generating *extensions* of that metaphor – new descriptions of a target are found which, in general, are ill-formed and metaphorical. These metaphorical descriptions are,

however, not without use, as they can be the antecedent descriptions in reference resolution. Such reference resolution which uses metaphorical antecedents will be termed 'metaphorical reference resolution' and the antecedents will be termed 'antecedent metaphors'.

4.2 Metaphorical reference resolution in systematic metaphor

In the above example, the antecedent metaphor used in metaphorical reference resolution was found as a consequence of a previous *input* metaphor – in this case, the current input represents an *extension* of the previous input metaphor. It is, on the other hand, possible for the antecedent metaphor to be found as a consequence of a known *systematic* metaphor, in which case the current input represents a *manifestation* of that systematic metaphor.

As an example, consider EMOTIONALITY IS TEMPERATURE. The core analogy underlying this systematic metaphor views a person as a physical object and their emotionality as its temperature. This analogy has two targets (a person and their emotionality), and two sources (a physical object and its temperature). Definitive entities provide the ideal way of representing this core analogy, since by associating the metaphorical descriptions above with the definitive person $\langle \text{person} \rangle$, it is ensured that such descriptions are inherited by all other persons.

The core analogy can be represented thus:

[$\langle \text{person} \rangle$ is-analogous-to $\langle \text{object} \rangle$
and $\langle \text{emotionality} \rangle$ is-analogous-to $\langle \text{object's temperature} \rangle$]

where, $\langle \text{person} \rangle$ is the definitive person, $\langle \text{emotionality} \rangle$ is the emotionality of $\langle \text{person} \rangle$ (i.e., another definitive entity in a definitive relationship with $\langle \text{person} \rangle$), $\langle \text{object} \rangle$ is the definitive $\langle \text{object} \rangle$, and $\langle \text{object's temperature} \rangle$ is, of course, the temperature of $\langle \text{object} \rangle$.

This core analogy is identical in form to any other analogy between definitive entities, and as such should be considered as simply another background analogy representing a piece of commonsense knowledge – it represents a piece of knowledge about how people and their emotionality are described, and it can be used in description inheritance in the same way as any other background analogy. For example, it licenses a metaphorical description of the relationship between $\langle \text{person} \rangle$ and $\langle \text{emotionality} \rangle$:

$\uparrow\uparrow$ $\langle \text{person} \rangle, \langle \text{emotionality} \rangle$
 \Rightarrow $\langle \text{object} \rangle, \langle \text{object's temperature} \rangle$
 \Downarrow $\langle \text{object's temperature} \rangle$ is $\langle \text{object} \rangle$'s temperature
 $\uparrow\uparrow$ $\langle \text{emotionality} \rangle$ is $\langle \text{person} \rangle$'s temperature.

This is in addition to the intrinsic description of the relationship

$\langle \text{emotionality} \rangle$ is $\langle \text{person} \rangle$'s emotionality.

The core analogy, then, might be summed up in the slogan "a person can be seen as an object provided their 'temperature' is interpreted as their emotionality".

Suppose that it is known that Sally is a person, then descriptive analogy has it that $\langle \text{Sally} \rangle$ is analogous to $\langle \text{person} \rangle$. Chaining analogies gives a metaphorical description of Sally's emotionality:

- 1: [$\langle \text{Sally} \rangle$ is-analogous-to $\langle \text{person} \rangle$
and $\langle \text{Sally's emotionality} \rangle$ is-analogous-to $\langle \text{emotionality} \rangle$]
 - 2: [$\langle \text{person} \rangle$ is-analogous-to $\langle \text{object} \rangle$
and $\langle \text{emotionality} \rangle$ is-analogous-to $\langle \text{object's temperature} \rangle$]
- $\uparrow\uparrow_1$ $\langle \text{Sally} \rangle, \langle \text{Sally's emotionality} \rangle$
 $\uparrow\uparrow_2$ $\langle \text{person} \rangle, \langle \text{emotionality} \rangle$
 $\uparrow\uparrow_2$ $\langle \text{object} \rangle, \langle \text{object's temperature} \rangle$
 \Rightarrow $\langle \text{object's temperature} \rangle$ is $\langle \text{object's temperature} \rangle$
 $\downarrow\downarrow_2$ $\uparrow\uparrow \langle \text{emotionality} \rangle$ is $\langle \text{person's temperature} \rangle$.
 $\downarrow\downarrow_1$ $\uparrow\uparrow \langle \text{Sally's emotionality} \rangle$ is $\langle \text{Sally's temperature} \rangle$.

This description of Sally's emotionality as her temperature can be used to interpret Searle's example (seen in chapter 2)

(3) *Sally is a block of ice.*

The intended meaning of this utterance, that Sally is unemotional, was seen to be beyond the abstraction approach, as it depended crucially on interpreting an abstracted feature of ice, viz coldness, *metaphorically*. The initial interpretation of (3) is the input analogy

[$\langle \text{Sally} \rangle$ is-analogous-to $\langle \text{block of ice} \rangle$]¹

and the interpretation of (3) can be achieved as follows:

- $\uparrow\uparrow$ $\langle \text{Sally} \rangle$
 $\uparrow\uparrow$ $\langle \text{block of ice} \rangle$
 \Rightarrow $\langle \text{block of ice} \rangle$ is *cold*
 \Rightarrow $\langle \text{block of ice's temperature} \rangle$ is *low*²
 $\downarrow\downarrow$ $\uparrow \langle \text{Sally's temperature} \rangle$ is *low*
 $\langle \uparrow \rangle$ $\uparrow \langle \text{Sally's emotionality} \rangle$ is *low*.

As it happens, both of the final two sentences in this sequence are well-formed, so it would be possible to stop at the first and accept that as an interpretation of (3). Here, though, that interpretation is rejected and the second sentence, to the effect that Sally is unemotional, is accepted in preference. More will be said about choosing between interpretations later.

Notice that the metaphorical reference resolution is triggered by reference to Sally's temperature, which is the central linking idea behind all examples of EMOTIONALITY IS

¹ $\langle \text{block of ice} \rangle$ is rather unlikely to be a definitive entity present in the system, but it might well be constructed from $\langle \text{block} \rangle$ and $\langle \text{ice} \rangle$. For simplicity here, it is assumed to be available.

² This description is treated here for simplicity as an intrinsic description of $\langle \text{cold-thing} \rangle$, however it is analyzed further in MINT using the analogy [$\langle \text{cold-thing's temperature} \rangle$ is-analogous-to $\langle \text{little-quantity} \rangle$]. The use of the word 'low' is of course an instance of MORE IS UP. The co-occurrence of two systematic metaphors is no problem for descriptive analogy, but for simplicity the issue is ignored in this example.

TEMPERATURE. This means that this method of metaphorical interpretation is general to all utterances which make reference, explicit or implicit, to a person's temperature, examples such as

- (4) *John is a warm person*
- (5) *Sally is frigid*
- (6) *Mary is a bonfire.*

The technique of using known core analogies to derive antecedent metaphors for use in metaphorical reference resolution is the key to processing a great many manifestations of systematic metaphor. For instance, the example used in the informal look at processing earlier in this chapter, THE MIND IS A BRITTLE OBJECT, can be handled in just the same way, taking the underlying analogy to be

[⟨person⟩ is-analogous-to ⟨structure⟩,
⟨confidence⟩ is-analogous-to ⟨structural-integrity⟩
⟨strength-of-character⟩ is-analogous-to ⟨strength⟩.]

Knowledge of this analogy enables references to a person's structural integrity to be interpreted as references to the person's confidence.

A more complex example

The preceding examples make use of metaphorical reference to various *properties* of a person, their strength, temperature, confidence, and so on, which are entities in special relationships with that person. The process of metaphorical reference resolution is, however, capable of dealing with more general predicative relationships. Take, for example, TIME IS A MOVING OBJECT. Here, the elapsing of time is seen as movement, and this can be captured in an analogy between the definitive elapsing and the definitive movement:

- 1: [⟨time-interval⟩ is-analogous-to ⟨moving-object⟩,
⟨elapsing⟩ is-analogous-to ⟨movement⟩.]

An utterance such as

- (7) *The summer rolled by*

can then be interpreted as follows:

Initial processing of (7) yields two input analogies:

- 2: [⟨summer31⟩ is-analogous-to ⟨time-interval⟩]
- 3: [⟨summer31⟩ is-analogous-to ⟨rolling-object⟩
and ⟨event31⟩ is-analogous-to ⟨rolling⟩,]

where ⟨event31⟩ is the event being described in (7).

The first of these in conjunction with the background analogy above yields a metaphorical description of the elapsing of <summer31>:

\uparrow_2 <summer31>, <elapsing31>
 \uparrow_1 <time-interval>, <elapsing>
 \uparrow_1 <moving-object>, <movement>
 \Rightarrow <movement> *is the movement of* <moving-object>
 \downarrow_1 $\uparrow\uparrow$ <elapsing> *is the movement of* <time-interval>
 \downarrow_2 $\uparrow\uparrow$ <elapsing31> *is the movement of* <summer31>.

The latter analogy, in conjunction with a background analogy between <rolling-object> and <moving-object>,

4: [\uparrow <rolling-object> is-analogous-to <moving-object>
and <rolling> is-analogous-to <movement>]

enables the following reasoning (where the antecedent metaphor of the resolution step is the description of <elapsing31> derived above):

\uparrow_3 <summer31>, <event31>
 \uparrow_3 <rolling-object>, <rolling>
 \uparrow_4 <moving-object>, <movement>
 \Rightarrow <movement> *is the movement of* <moving-object>
 \downarrow_4 \uparrow <rolling> *is the movement of* <rolling-object>
 \downarrow_3 $\uparrow\uparrow$ <event31> *is the movement of* <summer31>
 $\langle\uparrow\rangle$ \uparrow <event31> *is* <elapsing31>.

In other words, the event being described in (7) is the elapsing of the summer. More subtle 'fleshing out' of this basic interpretation can be achieved by considering further background analogies involving <rolling> capturing, say, smoothness and uniformity of motion.

It should be clear that similar reasoning can be applied to any utterance in which a time interval is described as though it were moving in some fashion.

4.3 Associated metaphors

Metaphorical reference resolution is an approach suitable for the interpretation of many utterances involving systematic metaphor, but will only work when metaphorical reference is made to some functional attribute of an entity – *the* temperature of an object, *the* emotionality of a person, *the* elapsing of a time-interval, and so on.

There are, however, cases when reference is made to an incidental property of an entity, such as *a* child of a person, *a* reading of a book, and *a* criticism of an argument. In these cases it is necessary to use a modification of the reasoning outlined above. This modified processing is called 'generalized metaphorical reference resolution', and is accomplished by the use of 'associated metaphors'.

UNDERSTANDING IS SEEING is an example of a systematic metaphor in which the straightforward metaphorical reference resolution process is not by itself adequate. UNDERSTANDING IS SEEING is one of a group of closely associated systematic metaphors:

- (8) UNDERSTANDING IS SEEING
 IDEAS ARE OBJECTS
 DISCOURSE IS A LIGHT MEDIUM:
I see what you're saying.
It looks different from my point of view.
Now I've got the picture.
Let me show you the idea.
That is an interesting observation.
The argument is clear.
The discussion was opaque.

Here, ideas are seen as objects, understanding an idea is described as 'seeing' it, and the more easily an idea is 'seen', the more easily it is understood.

Consider the utterance

- (9) *I see the idea.*

There is no unique attribute of the idea that is being referred to in this example, rather it is *an observation of the idea*.

The two relevant core analogies in this utterance are

- 1: [*<idea>* is-analogous-to *<object>*]
- 2: [*<understanding>* is-analogous-to *<seeing>*
 and *<understander>* is-analogous-to *<seer>*
 and *<understood>* is-analogous-to *<seen>*]

Where *<idea>* is the definitive idea, *<object>* is the definitive object, *<understanding>*, *<understander>*, and *<understood>* are definitive entities in the relationship of understanding,³ and *<seeing>*, *<seer>*, and *<seen>* are definitive entities in the relationship of seeing. These two *associated* metaphors can be summed up as "an idea can be regarded as an object *provided* 'seeing' is interpreted as understanding".

In addition to these two core analogies, there is a third background analogy available (as commonsense knowledge) for use in interpretation:

- 3: [*<seen>* is-analogous-to *<object>*]

which reflects the idea that, in the core sense of 'see', what is seen is an object. It is the conjunction of these three analogies that enables a 'seeing' of an idea to be interpreted as an understanding of the idea:

³ That is, *<understanding>* is the archetypal event of understanding, *<understander>* is the understander in that event, and *<understood>* is the idea which is understood.

Initial interpretation of (9) yields the input analogy

- 4: [(speaker31) is-analogous-to <seer>
 and <idea31> is-analogous-to <seen>],

which, when chained with analogy (3), shows <idea31> being described at though it were an object, i.e., this input utterance is a manifestation of IDEAS ARE OBJECTS. Since this systematic metaphor is *associated* with UNDERSTANDING IS SEEING, the reference to a 'seeing' of <idea31> can be resolved to an 'understanding' of <idea31>, yielding a paraphrase of (9) as

- (10) *I understand the idea,*

which is well-formed and can be accepted.

The precise mechanism for this processing is not easily expressed in the implementation independent notation of this chapter, but is described fully in chapter 6 as it is implemented in the MINT system.

4.4 Perspectives, interpretations, and acceptance

It has been seen that the result of metaphorical interpretation is sometimes only one of a number of possible interpretations. This is most obvious in the case of sentential metaphors, such as

- (11) *Sally was crushed,*

where there is a literal interpretation as well as a metaphorical interpretation (as a manifestation of THE MIND IS A BRITTLE OBJECT). It is also possible for there to be more than one metaphorical interpretation. An example of that has already been seen in the interpretation of (3): when considering the derived description

- (12) †<Sally>'s temperature is low

this could either be accepted at face value, or interpreted further as a manifestation of EMOTIONALITY IS TEMPERATURE.

In both these cases, the different interpretations correspond to different perspectives on Sally. In the literal interpretations, Sally is seen as a physical object by virtue of being seen as a body, a view which might be termed the physical perspective. In the metaphorical interpretations, the psychological perspective is adopted and she is again seen as an object, but this time by virtue of analogies in which she is considered as a thinking agent.

The idea of an interpretation corresponding to a perspective takes on a greater importance when multiple descriptions are produced in response to an input utterance. For example, (11) might be paraphrased as

- (13) *Sally was damaged*
- (14) *Sally was destroyed*
- (15) *Sally's structural-integrity was reduced*
- (16) *Sally's structural-integrity changed.*

These form a coherent interpretation as long as the same perspective is adopted throughout; if, on the other hand, the perspective is varied between the physical and the psychological, then these descriptions taken together do not form a coherent interpretation.

Another example showing the importance of maintaining a consistent perspective during interpretation is

- (17) *Sally was frosty at first, but soon warmed up.*

These issues of interpretations and perspectives will be discussed more thoroughly in the implementation described in chapter 6, where they are crucial to the control of processing.

Acceptance

In general, processing of an utterance results in a paraphrase in which a number of descriptions have been interpreted consistently according to a particular perspective on the target. Together, this group of descriptions constitutes an 'interpretation' of the input utterance.

Such an interpretation can be accepted or rejected on pragmatic grounds, that is, depending on whether it is seen as plausible in context. If it is rejected, then another interpretation might be possible as long as another perspective on the target can be found.

This acceptance of an interpretation is an acceptance of a number of well-formed descriptions as a whole. There is a problem, however, which is that individual descriptions within the interpretation might not be valid, as they are arrived at by a form of analogical reasoning, which is inherently unreliable. For example, in the interpretation of "John is an ogre", abstractions must be treated with caution, so while both of

- (18) *⟨John⟩ is a thing*
- (19) *⟨John⟩ is frightening*

are individually valid, neither of the following well-formed descriptions form part of the intended meaning:

- (20) *⟨John⟩ is mythical*
- (21) *⟨John⟩ is very tall.*

The individual descriptions within an interpretation must be regarded as *defeasible*, so that they can be overridden in the light of existing or future knowledge and expectations. The mechanism by which this can be done is not an issue addressed in descriptonal analogy,

which concentrates solely on how to derive interpretations. There are, however, a number of heuristics developed in other research into metaphor and analogy which may be useful in picking out the descriptions most likely to be intended by the speaker. In particular, Jaime Carbonell's 'invariance hierarchy' [Carbonell 82], Dedre Gentner's Structure Mapping Theory [Gentner 89], and Holyoak and Thagard's constraint-satisfaction theory [Holyoak and Thagard 89] provide such heuristics. All of these, for example, favour complex relational assertions over simple attributes of entities, and a likely approach to the problem of which individual descriptions within an interpretation to adopt would be to select a core of only the most favoured according to these heuristics.

4.5 Summary

In these two chapters, it has been shown how the Principle of Descriptive Analogy can be used to generate literal paraphrases of metaphors by abstraction, and of manifestations of known systematic metaphors by a combination of abstraction and (generalized) metaphorical reference resolution. The form of processing used is, however, equally applicable to literal input utterances, and so descriptive analogy has achieved much in being a theory of metaphor that does not treat metaphor as deviant, but rather as the norm.

The outline processing is as follows:

- (1) An input utterance (literal or metaphorical) is initially interpreted as an input analogy (or, for more complex utterances, a set of input analogies) in accordance with the Principle of Descriptive Analogy.
- (2) The targets of this analogy are redescribed by description inheritance, either directly from the sources or indirectly by chaining analogies.
- (3) Some of these descriptions may themselves be interpreted metaphorically by (generalized) metaphorical reference resolution.
- (4) Descriptions of the targets which are judged to be well-formed (relative to the system's dictionary) are combined to form an 'interpretation', or literal paraphrase.
- (5) A consistent perspective is maintained on the targets during this processing, and the resulting interpretation can be accepted or rejected on deep semantic and pragmatic grounds. If an interpretation is rejected, a different interpretation may be found by processing with alternative perspectives on the targets.

In general, an interpretation produced by this mechanism will consist of a number of well-formed descriptions of the targets, which will each make a contribution to the overall interpreted 'meaning'. This meaning may differ from the intended meaning of the speaker in

two ways. Firstly, some of the components of the interpretation may not have been intended by the speaker, (for example, the description "John is large" produced from the input "John is an ogre"). It is likely that some of these descriptions may be filtered out as semantically at odds with prior knowledge or pragmatically unlikely. In any case, individual descriptions in an interpretation should be regarded as defeasible. Secondly, part of the meaning of a metaphorical utterance may be lost due to inadequate knowledge in the system, for example when a suitable systematic metaphor is not known, the interpretation process becomes one of abstraction. In this case, it is reasonable to suppose that the *partial* meaning recovered will still be of use.

The uniform handling of input utterances, both literal and metaphorical, is largely due to the use of definitive entities in descriptonal analogy – ordinary semantic knowledge (including dictionary definitions), such as the 'fact' that mothers are ancestors, can be represented in just the same way as the analogies underlying metaphors, and in particular the core analogies underlying systematic metaphors.⁴

Descriptonal analogy has been presented in an implementation independent form in these chapters. For this reason it has not been possible to describe in detail many of the processes, in particular the processes of generalized metaphorical reference resolution. Also, there has not been any discussion on the procedures required to *search* for possible interpretations. In the next two chapters, an implementation will be presented where this level of detail will be given.

⁴ The analogies underlying input metaphors are not fundamentally different from core analogies, except perhaps that core analogies tend to be between definitive entities (background analogies), whereas the analogies underlying metaphors tend to have discourse entities as their targets (input analogies).

5. DREP

We now turn to the practical implementation of descriptonal analogy. This falls naturally into two parts as follows. Firstly, there is the analogical knowledge representation DREP, which is the subject of this chapter. Secondly, there are the algorithms used to exploit this knowledge in language processing. These are embodied in the MINT system, which is the topic of the next chapter.

Overview

This chapter describes DREP as a knowledge representation, without concentrating on how it is to be used in MINT.

5.1 reviews the overall requirements of DREP and motivates its implementation as a fully intensional, homogeneous semantic network. 5.2 presents the fundamentals of DREP – its single type of node, the ‘concept’, which represents the c-entities of descriptonal analogy, and the single type of link – the ‘d-link’, which is a structural link representing analogies. This section also describes how chains of d-links can be ‘composed’ to give ‘composite’ d-links, and ‘widened’ to increase their information content. 5.3 discusses the frame interpretation of DREP. 5.4 reviews the matching operations in the network. 5.5 considers giving a fully intensional semantics to DREP based on Castañeda’s theory of guises. 5.6 reviews the various representational idioms used in MINT, covering nouns, verbs, adjectives, event structure, and prepositional phrases. 5.7 compares DREP as a knowledge representation with other representations in terms of representational power and suitability for use in language processing. 5.8 looks at how DREP is used in MINT, and in particular the correspondence of d-links and descriptions, which is the key to MINT’s handling of well-formedness.

5.1 Introduction

DREP is a semantic network formalism whose nodes represent c-entities (both discourse entities and definitive entities) and whose structured links represent analogies (both input analogies, generated as a result of input utterances, and background analogies, which represent a form of commonsense knowledge). Before giving a detailed presentation of DREP, the factors motivating the formalism are discussed below.

5.1.1 Requirements of the representation

There are a number of requirements for DREP which arise from the general methodological aims of this work and from the specific features of the theory of descriptonal analogy. These requirements are outlined below.

Analogyes

As should be clear from the outline of descriptonal analogy given in the last two chapters, DREP is primarily required to represent c-entities and analogyes. In descriptonal analogy, analogyes form the basic mechanism by which entities are related – not only are analogyes seen as the mechanism responsible for the generation and inheritance of *metaphorical* descriptions, but *literal* descriptions too are seen as being arrived at by analogy with definitive entities. The consequence of this ubiquity is that efficient storage and retrieval of analogyes should be of prime consideration in the representation.

Commonsense knowledge

DREP is only intended to represent *descriptonal* knowledge, that is, knowledge about how an entity can be described, both by itself and in its relationships with other entities. DREP is not intended to be a general knowledge representation although, not surprisingly, this descriptonal knowledge strongly reflects the more conventional knowledge that general knowledge representations attempt to capture.

For example, knowing that <Tweety> can be described as 'a canary' means that <Tweety> can also be described as 'a bird', an observation which is conventionally attributed to the 'commonsense' knowledge that all canaries are birds. In descriptonal analogy, on the other hand, these inherited descriptions are just that – descriptions – they are not required to be statements of objective fact. A particular point to make is that DREP is not required to support full logical inference, and logical inconsistencies are not only to be tolerated, but are essential as they are only to be expected in metaphors.

In short, DREP is required to represent descriptonal knowledge which reflects general knowledge, but this knowledge is not to be interpreted in the conventional way. There will be further discussion of the relationship between descriptonal knowledge and conventional knowledge later in this chapter.

Breadth and depth of knowledge

While DREP does in a sense represent commonsense knowledge, that knowledge is spread rather thinly over a large area: the knowledge covered is principally about the *core* senses of words, which might cover any number of domains,¹ rather than senses directly applicable to some chosen domain of discourse.

This is a rather different situation from the more usual position in analogical reasoning, where a small domain is modelled in considerable detail. A consequence of this broad and shallow semantic coverage is that DREP needs to be very flexible in what it can represent. Quite crude approximations will have to be made, and the system as a whole cannot rely on anything like completeness in its knowledge.

Multiple perspectives

It was also seen in the theoretical account of the sort of processing required of MINT that it is possible to arrive at more than one interpretation of a metaphorical input. The different interpretations were seen to be reflections of a choice of perspective on the entities involved, for example, two perspectives on a person were given as the person seen as a physical body and the person seen as a thinking agent.

The ability to represent such 'multiple perspectives' is a frequent requirement of knowledge representations and DREP is no exception.

Simplicity

A final point is a restatement of the methodological aim of simplicity. This was seen as a very important factor in the design for a number of reasons. Firstly, DREP was developed as the foundation for an experimental system, so modification during its implementation was only to be expected. The ease with which such modifications could be made would have been considerably reduced had the knowledge representation been more complex. Secondly, it was never intended that this implementation should be used directly as a component of a larger project. Instead, it is envisaged that the ideas and methods used in MINT should be re-implemented in a larger, and perhaps already existing, system. Naturally, the less complex MINT and DREP are, the easier this re-implementation in a different programming context would be. Finally, as MINT is the experimental vehicle for the development of a new theory of metaphor, simplicity in the implementation makes it easier to see the theoretical wood,

¹ Where 'domain' is an informal term for 'subject area' – domains have no formal status in DREP.

despite the implementational trees.

5.1.2 The implementation of DREP

DREP has been implemented as a fully intensional semantic network with structured links giving it a strong frame flavour. The reason for the choice of semantic network over other representations, such as logical form or a primitive based representation, is to do with the twin issues of notational simplicity and efficiency.

Notational simplicity

One of the reasons given for having simplicity as a methodological aim of the implementation was that this would render the underlying ideas of the system more visible and hence easier to identify and incorporate into a more comprehensive system. An extremely important factor in the visibility of underlying mechanisms is choice of notation – the more naturally the notation can accommodate the knowledge structures associated with descriptive analogy (i.e., analogical mappings), the more apparent these mechanisms become.

It turns out that the analogical mappings central to the operation of descriptive analogy cannot be naturally represented in either a logical notation or a semantic primitives notation, since in both cases the result is somewhat verbose, whereas in the semantic network / frame representation developed here, the notation is very concise and easy to follow. A rough formulation of descriptive analogy in a logical notation is given at the end of this chapter, where the clumsiness of the result is clearly visible.

Efficiency

In the processing required for the interpretation of metaphors, many analogies have to be combined and matched in an extensive knowledge base. The use of a semantic network means that relevant analogies can be found quickly and efficiently by their positions in the network. Although efficiency is not an overriding concern in this experimental system – clarity for example, is considered of greater importance – the sheer scale of these operations demands an efficient implementation.

5.2 Basic DREP

As is usual in semantic networks, DREP representations are made up of nodes and links.

Nodes

The nodes of DREP are called 'concepts'. Concepts correspond to the c-entities of descriptional analogy, each is known by a unique name, which will be indicated in sanserif font. For example, John, man, and person are all concept names.

All concepts enjoy equal status in DREP – there are no primitive concepts with special meaning in the representation. Concepts only acquire meaning by virtue of their *position* in the network, that is, their *relationships* with other concepts.

Some concepts, in addition to their links to other concepts within the network, have direct links into the system's lexicon specifying their intrinsic descriptions (in logical form). Such concepts are the representations of the definitive entities of descriptional analogy. There is no stipulated limit on the complexity of these intrinsic descriptions, but in practice they are only very basic, corresponding to single words or predicates. For example, man is linked only to the unary predicate MAN, and person to the unary predicate PERSON. More complex descriptions, and in particular dictionary-like definitions, are built compositionally as a result of analogical relationships between concepts *within* the network.

This linkage to the lexicon is the ultimate means by which concepts within the network are anchored to the 'outside world' and so ultimately how they derive their interpretations; the *names* of concepts, for example, are invisible to an observer of MINT and so are only incidentally relevant to the meanings of concepts – DREP would function just as well if its concepts were given nonsense names. The nature of this interface between the representational network and the outside is described fully in the next chapter.

Apart from having a name, links to other concepts, and possible links to the lexicon, a concept has no internal structure. All information about concepts resides in the complex links connecting them.

Links

There is only one type of link in DREP² and it represents the analogical mappings of descriptional analogy. It is a complex link connecting groups of concepts ('sources' and

² Although there are a couple of labels, or 'features', which can be applied to these links, viz literal / metaphorical and type i or p. The significance of these features is discussed at the end of this chapter.

'targets') and is known as a 'description inheritance link', or 'd-link' (hence the name DREP for 'd-link representation').

A d-link is a bundle of 'maps', each of which links two concepts, a 'target concept' and a 'source concept'. The number of maps in a d-link is known as the 'width' of that d-link and can be arbitrarily large. The width corresponds directly to the number of sources in the represented analogy.

D-links can be represented graphically as in figure 7.³ This figure shows two d-links; the first has only one map (i.e., has width 1) and is the representation of the analogy

[[<dog> is-analogous-to <animal>]]

the second has width three and is the representation of the analogy underlying the systematic metaphor UNDERSTANDING IS SEEING:⁴

[[<understanding> is-analogous-to <seeing>,
<understander> is-analogous-to <seer>,
<understood> is-analogous-to <seen>]]

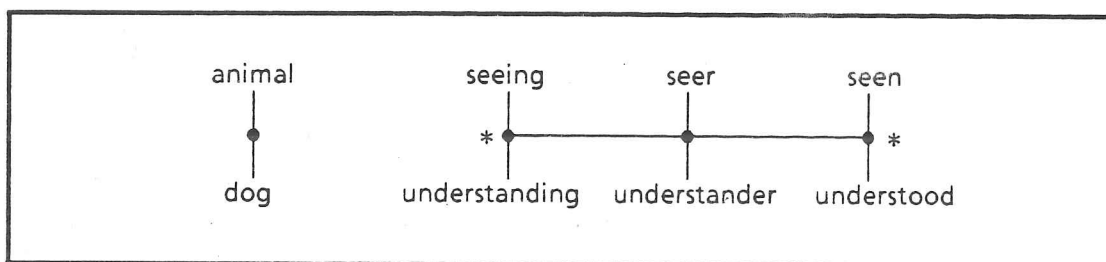


Figure 7: Example d-links of widths one and three

There are several points to be made about this graphical notation:

Firstly, d-links are asymmetric with respect to source and target concepts: source concepts appear above the d-link and target concepts below. This convention parallels the convention of drawing the source domain above the target domain in the diagrammatic representation of analogies in chapter 3.

D-links, as has already been pointed out, are essentially bundles of maps. These maps are represented in the diagrams by vertical lines linking source and target concepts, and the horizontal lines joining the maps together indicate how they are bundled to form the d-link.

³ There is a possible source of confusion in this notation for readers familiar with Alshawi's MEMORY formalism [Alshawi 83, 87], whose Corresponds: links bear a syntactic resemblance to d-links of width 2. In the DREP notation, these width 2 links are essentially 'H' shaped, whereas Alshawi's would have been 'I' shaped. The DREP notation is more suitable here, as it is easily extended to cover greater widths.

⁴ The * labelling on this d-link marks it as metaphorical – one of the two features discussed in a previous footnote. This labelling is to do with the determination of well-formedness and should be ignored for the present.

The lines used to indicate maps will not always be drawn strictly vertically, since some distortion is often necessary to represent more than one d-link on the same diagram. The up-down orientation reflecting the source-target distinction will, on the other hand, always be preserved.

This up-down convention leads to the idea of descriptions filtering *downwards* from source concepts to target concepts. Concepts do not, however, necessarily form a strictly hierarchical structure, or even a tangled hierarchy with a clear notion of top and bottom, as there is nothing to prevent *cycles* of d-links arising in the network. Such cycles could not be drawn maintaining the up-down convention, but the problem does not often arise as only a few d-links are ever represented on a single diagram. The extra clarity lent by the convention to the diagrammatic representation makes perseverance worthwhile.⁵

The ordering of maps in a d-link is of no consequence at all, so the two d-links shown in figure 8 are completely equivalent. All target concepts have equal status with respect to the d-link, as do all source concepts. The order of maps in the diagrammatic representation of d-links is frequently swapped around to avoid clashes between links sharing sources or targets.

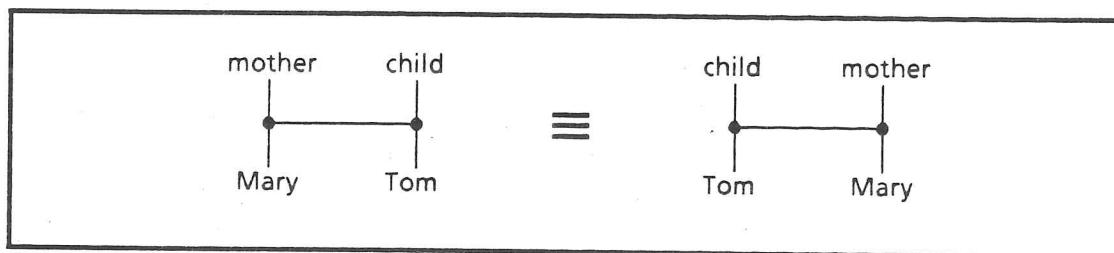


Figure 8: The ordering of maps is immaterial

To reiterate, the d-link is the only type of link in DREP. There are a couple of labels which can be attached to d-links to facilitate processing, but these are of minor significance in DREP itself – all d-links represent analogies.

5.2.1 Some more examples

In the above examples, some trouble has been taken to use words of English to name concepts. This, however, soon becomes a hopeless task, and in future hyphenation and abbreviation will be used widely. There is a standard set of suffixes corresponding frequently to traditional semantic cases, such as -ag for the agent of an action, -pat for the

⁵ In fact, the problem of representing cycles of d-links on the same diagram is overcome by duplicating concepts on the diagram. Such duplicated concepts will be highlighted by underlining.

patient, -inst for an instrument, -ev for an event, and so on. The use of these suffixes is intended only as a mnemonic, it does not indicate any commitment to the idea of semantic cases, and frequently they will be misused as an approximation (in the implementation, such names are generated semi-automatically). The name of a concept is of no significance at all to DREP, as has already been pointed out, concepts derive their 'meanings' from their connections into the lexicon, so concept names should not be taken too seriously.

Using this new concept naming convention, the earlier example of the analogy underlying the systematic metaphor UNDERSTANDING IS SEEING is shown in figure 9.

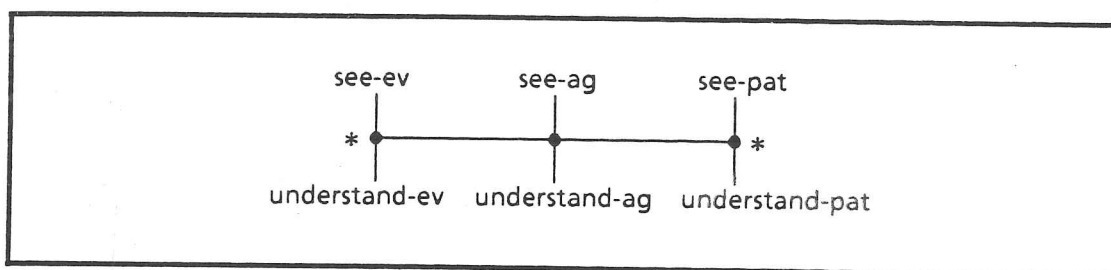


Figure 9: UNDERSTANDING IS SEEING

Figure 10 shows three more d-links of various widths involving definitive entities. Notice that these d-links between definitive entities reflect dictionary-like *definitional* information, for example 'kissing' is seen to be a form of 'touching', 'man' can be seen to have 'person' as part of its definition, and similarly 'mother' has 'ancestor' as part of its definition.⁶ It should be remembered, of course, that these are not explicit definitions of *words*, rather, the analogical knowledge in a DREP network combines cumulatively to give information about (definitive) *concepts*, and this information is understood as applying to the words in the intrinsic descriptions of the concepts involved.

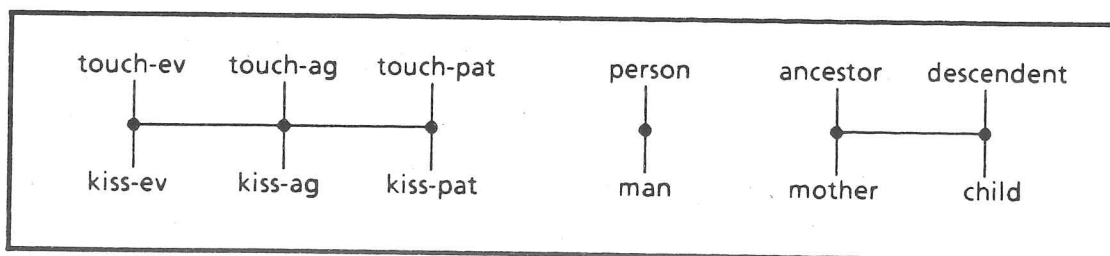


Figure 10: D-links between definitive entities

Figure 11 shows d-links between definitive entities and discourse referents, that might result

⁶ The multiple perspective mechanism discussed shortly has the effect of fleshing out these definitions.

from the inputs⁷

- (1) *John is a man*
- (2) *Dick kissed Mary.*

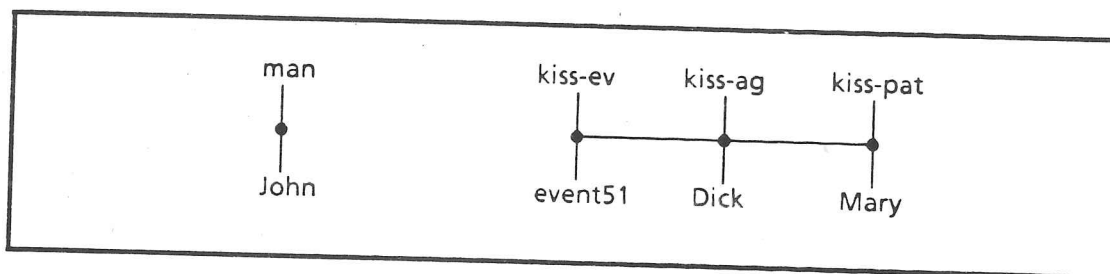


Figure 11: "John is a man" and "Dick kissed Mary"

Notice that because of the analogical semantics of DREP and the fact that the concepts involved are regarded as individuals (and *not* as 'generic' concepts), there is no need to mark these links as 'instantiations' – they simply represent analogies between (what happen to be) discourse entities and definitive entities. There is no explicit type / token distinction, since there are no explicit types. This is a distinguishing feature of DREP as compared to other semantic network formalisms; more will be said on this point later in this chapter.

Figure 12 shows how two d-links can represent different perspectives on a concept – one views Mrs. Thatcher as the prime minister of UK and the other views Mrs. Thatcher as the wife of Mr. Thatcher.

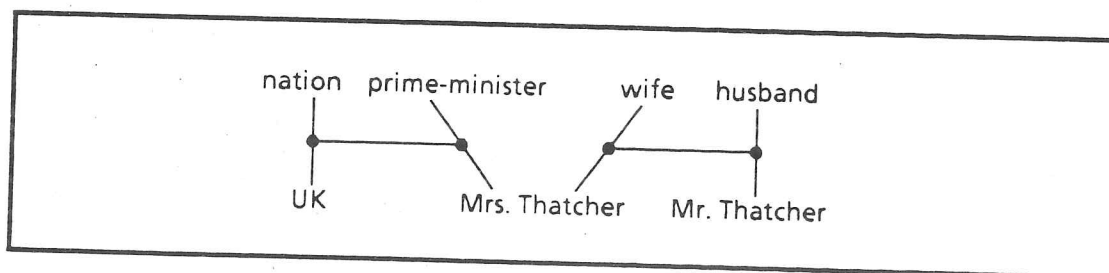


Figure 12: D-links forming multiple perspectives

It is possible for two or more maps of a d-link to share the same target concept, for example in the representation of

- (3) *John kicked himself*

which is shown in figure 13.

⁷ Recall that descriptonal analogy regards such utterances as expressing analogies between their referents and definitive entities.

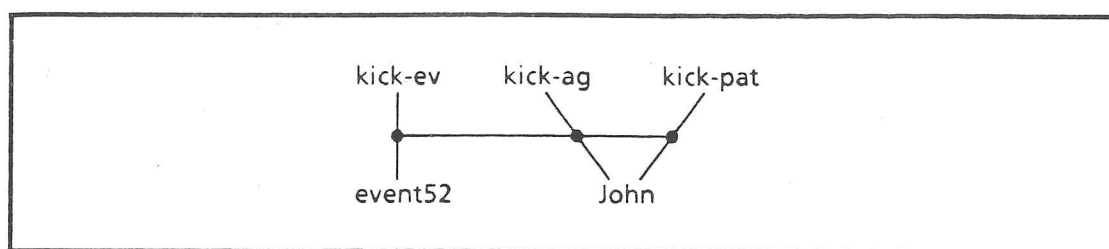


Figure 13: "John kicked himself"

It is not, however, permitted for two maps in a d-link to share the same *source* concept. The asymmetry in allowing of shared targets but not shared sources is due to the asymmetry in the direction of description inheritance – given descriptions of two source concepts, they can easily be applied to the same target concept, but in the case of a shared source, a description of it would somehow have to be divided up between the corresponding target concepts.⁸

5.2.2 Chains, composition, and widening

Chains

Concepts and d-links combine in a single data structure which takes the form of a highly structured network. D-links combine to form what are called 'chains' when they butt onto each other source end to target end, that is, when one or more sources of a 'lower' d-link also occur as targets of a second 'higher' d-link. In general, a chain can consist of any number of d-links (including one), as long as they join sources to targets. The number of d-links in a chain is known as the 'length' of the chain. Figure 14 shows examples of chains of length three and two.

Note that it is not necessary for the sources and targets of the d-links in a chain to match perfectly, it is enough for just one source of the 'lower' d-link simultaneously to be a target of the 'higher' d-link.

Composition of chains

According to the Principle of Descriptive Analogy, *all* descriptions of sources are inherited by targets. Descriptions of sources can arise by two routes: either they are fundamentally associated with the sources (intrinsic descriptions of definitive entities) or they are inherited from other entities as a result of further analogies. In the case of a chain of d-links, this

⁸ One might take the view that a description of a shared source should be applied equally to *all* corresponding target concepts, but it is not clear that this would always be desirable. The presence of shared sources would in any case considerably complicate operations carried out on the network, so it is better to rule them out completely at this stage.

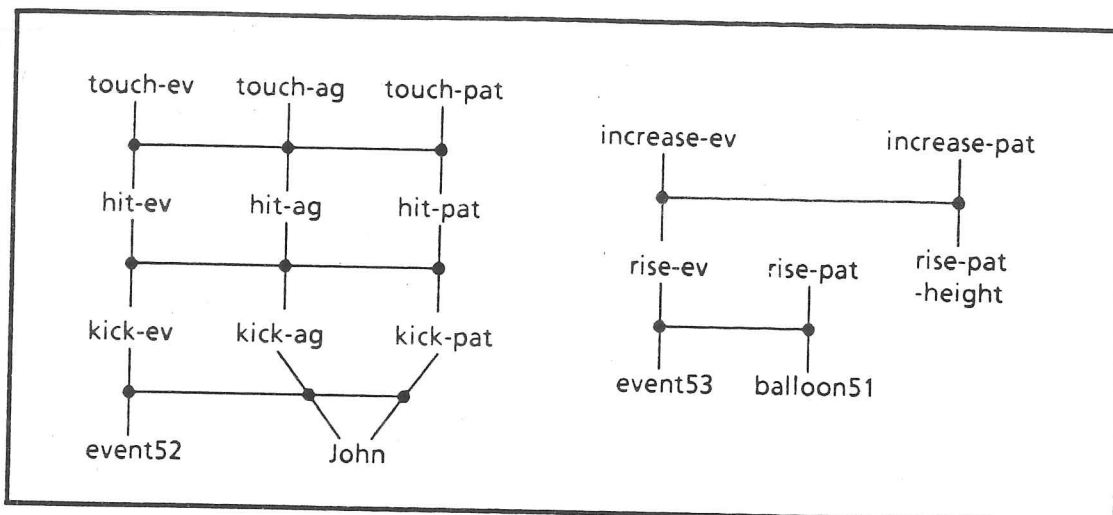


Figure 14: Chains of length three and two

means that descriptions of the sources of the top d-link in the chain can filter all the way down to the targets of the bottom d-link, exactly as if the chain were compressed into a single analogy between the top sources and the bottom targets.

This equivalence is made explicit in the process of 'composition': Given a chain in the network, it may be 'composed' to give a new d-link as follows: for each source of the top d-link, a path is traced down the maps of the d-links making up the chain until either it is not possible to continue any further or a target of the bottom d-link is reached. A new d-link is formed from maps corresponding to paths successfully traced down the entire length of the chain (see figure 15). The resultant d-link is called a 'composite d-link', and the chain that was composed is called the 'parent chain'.

Composite d-links represent a convenient way of handling a chain as a unit. This ability is used extensively in MINT, where chains are seen as representing descriptions of their targets.⁹

A composite d-link is for most purposes just like any other d-link, and in particular, it can itself take part in chains, which may then be composed to give further composite d-links. In the implementation, however, there is a need to keep track of the origins of d-links, and especially composite d-links, for a number of reasons. Firstly, a composite d-link is usually regarded as a sort of shorthand for its parent chain, and some operations on the composite d-link, notably widening (which is discussed next), are in fact implemented as operations on its parent chain. Secondly, the act of composing a chain leads to a duplication of information in the network, as the composite d-link is an explicit representation of an analogy that was implicit in its parent chain. In matching operations it is necessary to allow for this redundancy by ignoring the parent chain in favour of its composite d-link. Thirdly,

⁹ The correspondence of chains and descriptions is described at the end of this chapter.

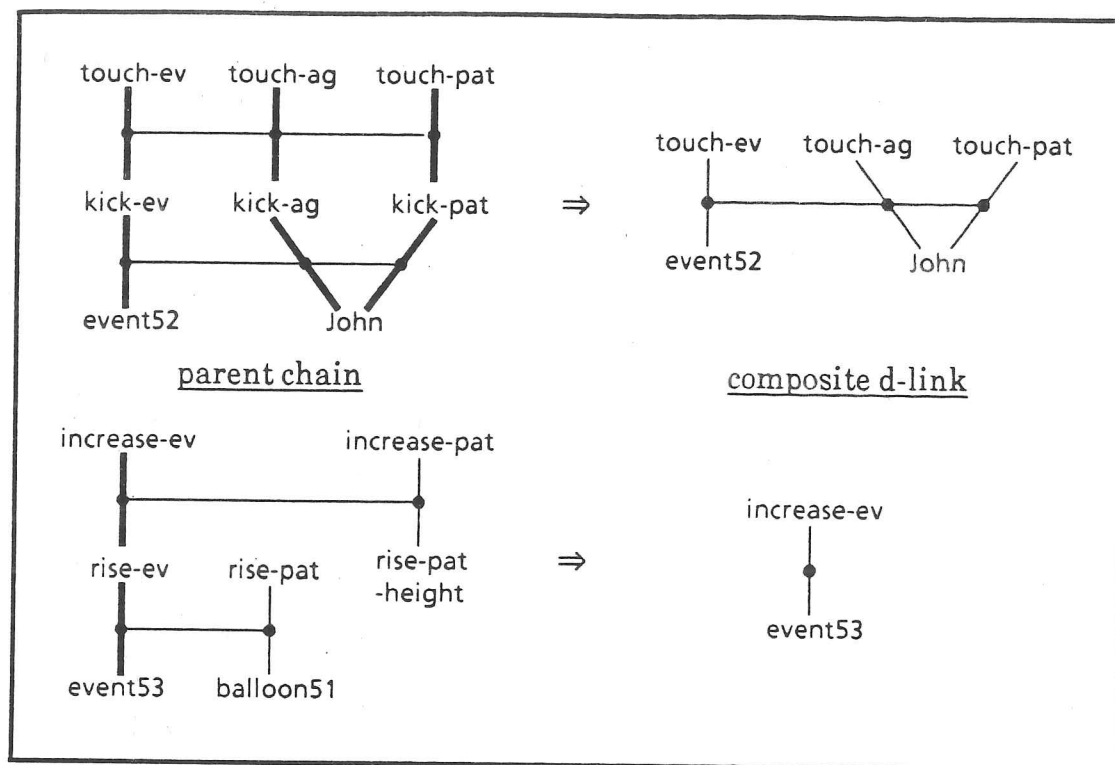


Figure 15: Composition of chains

there is a matter of housekeeping. Composition constitutes making a change to the network, and such changes need to be reversible, as backtracking is required in the case of multiple interpretations. Also, after processing a series of utterances, the network is returned to its original state by undoing the changes made rather than rebuilding it from scratch.

Widening

Widening is a second basic operation on d-links, but unlike composition, it alters an existing d-link rather than creating a new one. 'Widening' is the operation of adding extra maps to an existing d-link, an operation which corresponds to elaborating the represented analogy. A simple example of widening is shown in figure 16 where the single added map is indicated by dashed lines. As with composition, there is a certain amount of housekeeping associated with the widening operation to enable backtracking after an interpretation is generated.

The widening operation becomes rather more complex in the case of composite d-links, when it is actually an operation of widening the parent chain. In this case, some or all of the component d-links of the parent chain are themselves widened and extra concepts may need to be created for this purpose. Again, there is an asymmetry between source and target directions in the chain: widening is done starting from the source end, working towards the target end. The new source concept (assuming for simplicity there is only one map being added) is mapped down the chain as far as possible along existing maps; when no further

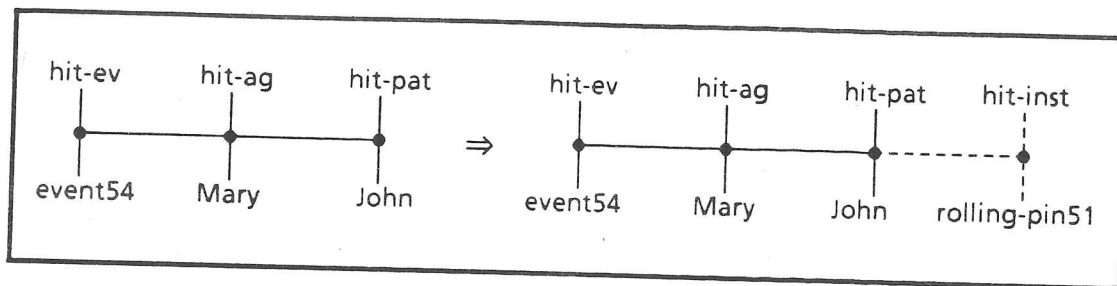


Figure 16: Widening a d-link

maps are available, new 'dummy' concepts are created to complete the path downwards, until finally the new target concept appears at the bottom of the chain.¹⁰ An example of the widening of a composite d-link and its parent chain is shown in figure 17.

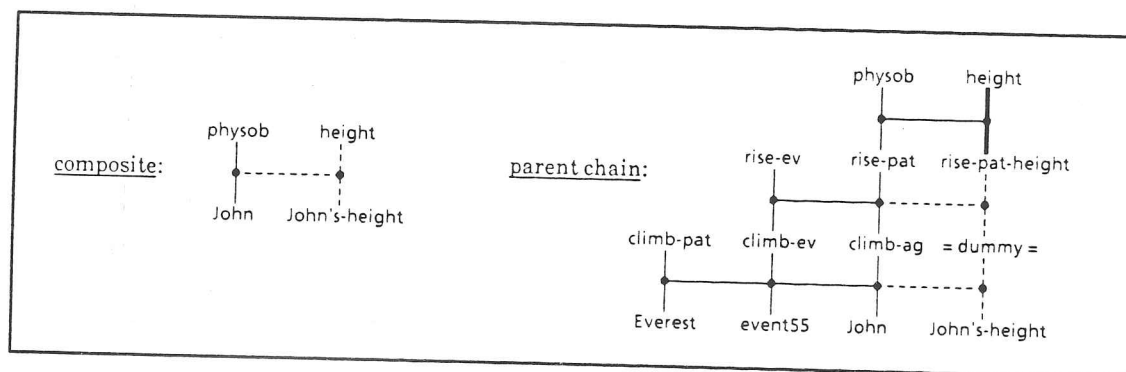


Figure 17: Widening a composite d-link

The reasoning behind this algorithm for widening a chain is again due to the direction in which descriptions are inherited: since widening is a method of augmenting an existing analogy, existing specifications of that analogy should be respected. A chain might already partially specify how a new source concept is to be interpreted, if a path can be traced part of the way down. These specifications are maintained in the widened chain and the widening operation is regarded as specifying how this chain of description inheritance from ultimate source to ultimate target is to be *completed*.

5.3 The frame interpretation of DREP

As has been previously remarked, there is a strong frame flavour about DREP, and it is the purpose of this short section to explain how this comes about.

¹⁰ Dummy concepts are simply anonymous concepts, which are created as required during widening to bridge gaps in the network.

The idea of frames is totally implicit in the representation – they can only be said to arise as a consequence of the relationships among concepts specified by intrinsic descriptions and d-links. The implicit frames are easiest to appreciate in the case of a group of definitive entities which are involved in a definitive relationship, as explained below.

Consider the the relationship of hitting, where there is an event of someone hitting something. A frame representation of 'hitting' might contain slots for event, agent, and patient, and for each event, a new copy of the frame would be made with these slots filled by the particular individuals involved, say event59, John, and man23 respectively in the event of John hitting a man (figure 18).

hitting-event	
event:	event59
agent:	John
patient:	man23

Figure 18: A frame for "John hit a man"

Now, definitive concepts can be seen as fillers of the same slots in an archetypal instance of the frame (figure 19), and because of the archetypal association of these concepts with particular slots in the frame, they may be regarded as uniquely *labelling* those slots.

hitting-event	
event:	hit-ev
agent:	hit-ag
patient:	hit-pat

Figure 19: Definitive concepts seen as slot fillers

A d-link which has these definitive concepts as sources can now be regarded as specifying that its targets fill the slots 'labelled' by the corresponding sources in another instance of the

frame. Furthermore, if another d-link appears directly below this one in a chain, then *its* targets can be considered as filling those slots in yet another instance of the 'hitting' frame, and so on (figure 20).

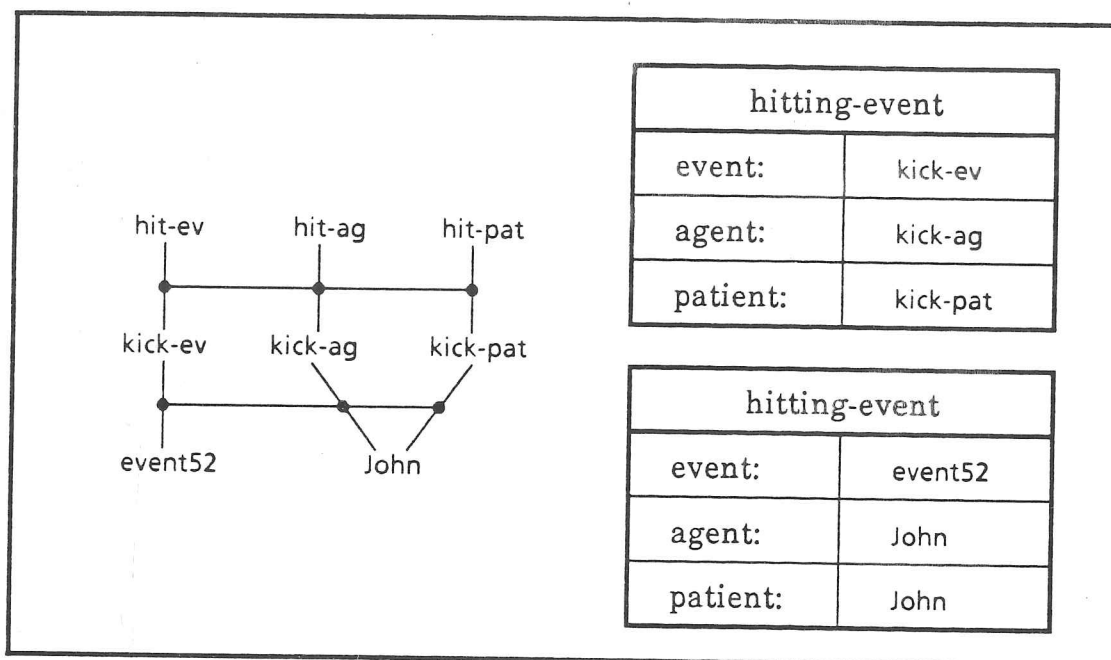


Figure 20: D-links specifying instances of frames

Because frames are implicit, there is no restriction as to which groups of concepts can combine in frame-like relationships. An implicit frame instance is 'created' whenever a group of concepts occur together at the same end of a d-link. These groupings may be different for different d-links, and this can be interpreted as many small implicit frames either overlapping or coalescing to form arbitrarily large frames.

It is, however, important to bear in mind that the idea of a frame is not a formal notion in DREP – concepts can only be said to be organized into frames by virtue of their being at the same end of some d-link or their being involved in the same intrinsic description. A frame cannot be handled as a unit, instances of frames are never actually created, all concepts within a frame have equal status (there is no owner concept, for example), and frames are rather hard to delimit due to the overlapping or coalescing described above. It is particularly important to bear in mind that a d-link is not an 'is-a' link, or a 'frame instantiation' link. It is a descriptive analogy link between (intensional) *individuals*.

5.4 Network matching

Interpretation in MINT is very largely a matter of matching d-links and chains generated as a result of input utterances against the pre-existing network which encodes both the system's commonsense knowledge and knowledge accumulated from previous input.

There are two types of matching used in processing, 'complete matching', which attempts to match a complete template d-link against chains in the network, and 'partial matching', which looks for chains that are '*consistent*' with its template:

Complete matching

The complete match operation takes a template d-link¹¹ and searches the network for chains which when composed yield composite d-links which have at least the maps specified by the template, and possibly more. In other words, the composite d-links obtained by composing matching chains should be widened versions of the template.

Figure 21 shows how complete matching might yield two matches for a template specifying Dick and Mary as its targets and touch-ag and touch-pat as the corresponding sources.

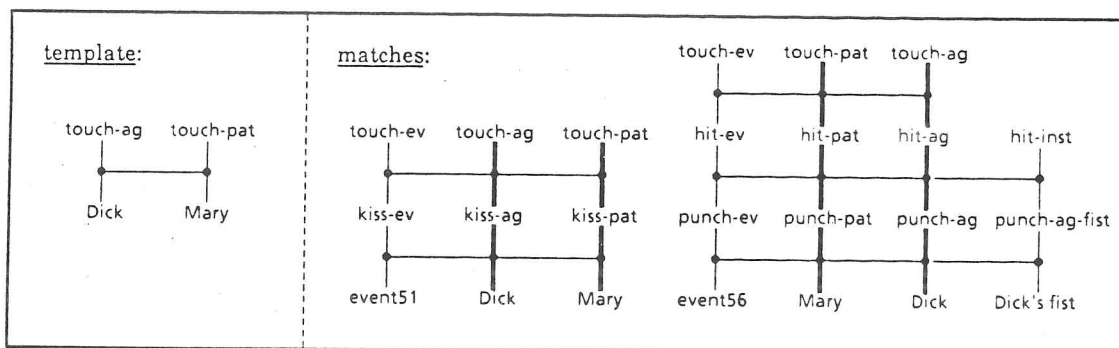


Figure 21: Complete matching

Partial matching

Partial matching is an operation similar to complete matching in that it takes the same sort of template and returns a list of matching chains, but it requires only a partial consistent match – at least one, but not necessarily all, of the maps specified in the template must be realized in each matching chain (partiality) and whenever a matching chain and the template have a source in common, the corresponding targets must also be the same (consistency).

¹¹ Technically, the template is not a d-link, but a specification of its constituent maps (it is not part of the network).

This is equivalent to saying that any matching chain could be widened using the maps of the template to give a legal result, i.e., one without multiple occurrences of a source concept.

Figure 22 shows an example of partial matching where only one of the two maps in the template matches the chain. The match is consistent, as the only other source in the template, *move-ev*, does not map to any target in the chain.

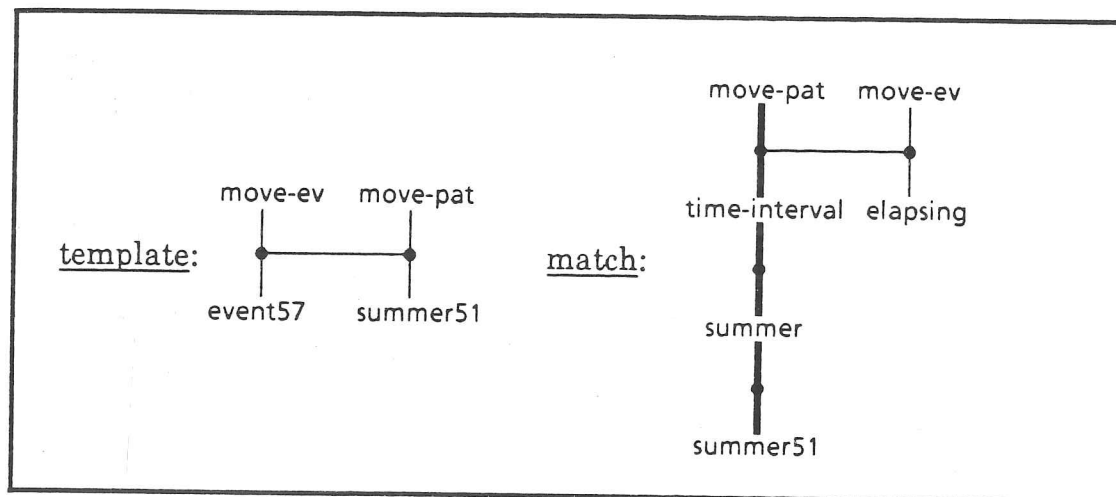


Figure 22: Partial matching

5.5 Semantics for DREP

The task of a semantics for DREP is to specify the link between the syntactic concepts and d-links of the representation and the sort of entities and relationships they are supposed to represent.

This section is at best a sketch of what such a semantics might look like – since the enterprise undertaken in this research has been the evolution of a theory of metaphor and its implementation, a process which cannot claim to be complete, it would be rather premature to attempt to build a rigorous semantic edifice at this stage. Also, since the handling of metaphor is only a small part of the greater enterprise of natural language interpretation, building a rigorous semantics for this component out of context would not be a particularly useful exercise.

Several factors which should be manifest in the semantics are, however, clear at this stage of the development process.

The first is that we are dealing with mental, or 'intensional', entities (c-entities). Some of these entities correspond in some way to objects or otherwise identifiable 'things' out there in the real world, but many, and perhaps most, correspond only to fictional entities or entities that have no independent 'existence' external to the system, such as is the case with

definitive entities.

The second major point is that the links of DREP, that is the d-links, do not express what might be called 'objective' facts about the entities they organize. They express facts about how these entities can be *described* both alone and in relation to other entities. This concentration on descriptions as opposed to objective facts again points to an intensional interpretation of DREP – descriptions, especially overtly metaphorical descriptions, are seen as artifacts of mental processing and not directly related to the outside world, although a correspondence in some cases can be seen. In this view, the analogies expressed by d-links are also seen as artifacts of mental processing rather than objective realities. This chimes in well with the intuition that it is possible to find analogies of varying quality anywhere simply by looking hard enough, and the corresponding intuition that there seems to be no practical limit to the ways in which entities can be described metaphorically.

So ideally the semantics given to DREP should be fully intensional. Another semantic network regarded as fully intensional is Stuart Shapiro's SNePS [Shapiro 79, 86], [Maida and Shapiro 82], which was designed to handle reasoning in intensional contexts such as the referentially opaque contexts of belief and knowledge. A paper by William Rapaport [Rapaport 85] considers giving an intensional semantics to SNePS. He first of all rejects a Montague-like approach involving possible worlds [Israel 83] on the grounds that it is not *fully* intensional and, by definition, it is not possible to represent *impossible* intensional objects (such as 'round squares' which are perfectly valid as objects of thought) in a *possible* worlds framework. Instead he proposes giving SNePS a Meinongian Semantics (after Alexius Meinong [Meinong 04]) which interprets all objects of thought as intensional objects which may or may not be associated with real world objects. Rapaport considers three recent formulations of Meinongian semantics, finally settling on Hector-Neri Castañeda's theory of guises as the most appropriate for SNePS. Guise theory is also well suited to form an outline semantics for DREP, although it is not sufficiently well formalized to be rigorous. Such an outline is presented below.

5.5.1 Guise Theory

Hector-Neri Castañeda's guise theory is a large and elaborate fully intensional ontological theory with just one sort of object, the *guise*. The theory is presented in considerable detail in [Castañeda 77], where he discusses its application as a general theory of perception, encompassing natural language, vision, and reasoning, but the portion of interest here is relatively straightforward.

Guises are specified by sets of properties. Typical properties might be 'being the present King of France', 'being bald', 'being round', 'being square', and so on. These properties are

collected into sets called 'guise cores', from which 'guises' can be obtained by applying the 'c' operator. Thus, some examples of guises being obtained from guise cores are:

- (4) $p = c\{\text{being round, being square}\}$
- (5) $q = c\{\text{being the tallest mountain}\}$
- (6) $r = c\{\text{being Everest}\}$
- (7) $s = c\{\text{being the Morning Star}\}$
- (8) $t = c\{\text{being the Morning Star, being a planet}\}$

Thus a guise can be said to be *the* intensional individual with exactly (no more and no less than) the properties specified in its guise core.

A guise core can be infinite, but only finite guises can be 'directly apprehended' in the mind and therefore used in cognition. It is a characteristic of actual existing objects that they are infinite propertied, so these, or rather the guises corresponding to them, cannot be directly apprehended and must be thought about via 'facets' – guises formed from finite subsets of their properties.

The properties listed in guise cores are 'internal' properties, which constitute the only internal properties of the relevant guises. These internal properties may even be inconsistent (as in p , the round square). There is in addition, an 'external' predication called 'consubstantiation' which amounts to the assertion that two or more guises are facets of the same 'real' thing. Consubstantiation is written ' C^* ', examples are

- (9) C^*qr
- (10) C^*st

where q , r , s , and t are the guises defined above. Roughly translated, these say that Everest is actually the same thing as the tallest mountain and the Morning Star is actually the same thing as the planet, the Morning Star.

Consubstantiation is an equivalence relation which essentially asserts that two intensional guises have the same *extension* (i.e., they *corefer*), although this extensional individual lies outside the theory, and so cannot be handled directly. Because there is no direct access to extensions, it is quite possible to talk about both the tallest mountain and Mt Everest without realizing that they are consubstantiated, and this is the key to how reasoning in opaque contexts can be modelled in guise theory – consubstantiation is an objective fact about guises and so not directly accessible to the mind, all that a mind can represent is *believed* consubstantiation.

There is an analogous external predicate 'consociation', written ' C^{**} ', which is used in the case of fictional 'extensions', for example,

- (11) $C^{**}(c\{\text{being Hamlet}\}, c\{\text{being the Prince of Denmark}\})$

The distinction between consubstantiation and consociation is useful in guise theory in characterizing existence, but the two can be regarded as equivalent in the current context.

5.5.2 Using guise theory as a semantics for DREP

There is a natural way of associating the concepts and d-links of DREP with the elements of guise theory. Concepts can be seen to denote guises and both d-links and intrinsic descriptions denote properties.

More specifically, an intrinsic description of a concept denotes the property 'can be described as ...' or 'can be described in relation to the guises ... as ...', and a d-link denotes the property 'can be described in the same way as the guise ...' or 'can be described in relation to the guises ... in the same way as the guise ... in relation to the guises ...'.

It is apparent that the properties denoted by d-links and intrinsic descriptions are complex in that they make reference to guises. This sort of property does not seem to be mentioned explicitly by Castañeda, but it is clear that he has complex properties such as these in mind when he formulates more sophisticated guises, such as 'propositional' guises which represent, not surprisingly, propositions.

Concepts denote the guises whose guise cores consist exclusively of the properties denoted by their intrinsic descriptions and d-links.¹² This ties in well with the idea of definitive entities being idealized intensional individuals having only the minimal number of properties consistent with their intrinsic description, and conversely the view that guises are 'things under a description', that is, things having focused on a subset of their properties.¹³

There is no *direct* rôle for consubstantiation (nor consociation) in this semantics, which might at first seem surprising, but consubstantiation is a matter of external predication – a matter of objective fact which is essentially inaccessible to a mind – and so we should *not* expect to see it in a representation of mental processing.¹⁴ There is, however, an implicit idea of consubstantiation in the processing associated with DREP. As operations are performed on the network, d-links are both added and modified, which corresponds to the changing of properties in guise cores. In guise theory, if a guise core changes, then the guise corresponding to the resultant core is a *different* guise – it is not simply a modification of the old guise. The appropriate construal for these operations then, is that attention is being shifted from one guise to a (believed) consubstantiated (or consociated) guise, so that although the guise may have changed, we are still reasoning about the same extensional (or fictional) entity.

¹² Note that only d-links *up* from the concept are considered here, that is, d-links which have the concept as a target.

¹³ [Castañeda 77] p. 324 ff.

¹⁴ It should be restated that this work is not an exercise in cognitive modelling, but it does involve a computational equivalent of mental processing, and the arguments in guise theory about direct apprehension of external predication carry through.

5.5.3 Summary

DREP is a fully intensional semantic network capable of representing non-existent and impossible objects, and whose links represent analogies. These specifications militate against giving DREP a 'standard' set-theoretic or possible worlds semantics and point towards a Meinongian semantics, as with SNePS. Guise theory is a well-developed, off-the-shelf Meinongian semantics that has been applied widely in explaining cognition. It turns out to be relatively easy to express the semantics of DREP in these terms.

5.6 Representational idioms in DREP

The examples processed by MINT require a fairly extensive range of semantic representation in DREP. Of course, there are many candidate ways of achieving these representations, and some sort of choice has to be made. Since it is not the object of this work to develop deep semantic models of the various phenomena that need to be handled, the representations used have been approximations chosen for their relative simplicity and consequent ease of implementation. Their use does not imply any commitment to any particular semantic theory or theories, and more to the point, the metaphorical theory underlying MINT processing does not rely on the use of these idioms.

5.6.1 Nouns

Nouns give rise to the simplest representations in DREP. Proper nouns are seen as indexing concepts directly, common nouns are seen as specifying d-links (i.e., analogies) to definitive concepts, and relational nouns are seen as specifying d-links to definitive concepts in definitive relationships (figure 23).

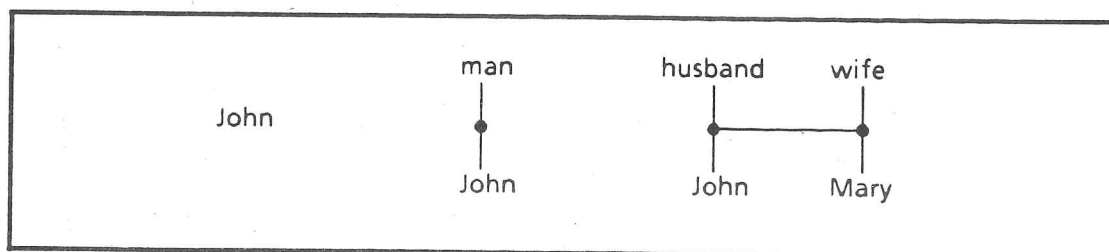


Figure 23: "John", "John is a man", "John and Mary are husband and wife"

5.6.2 Verbs

Verbs, like relational nouns, are seen as specifying relationships between concepts. The occurrence of a verb leads to the setting up of a d-link from the concepts filling their various argument places, or thematic rôles, to the corresponding definitive concepts. In addition to these thematic rôles, there is an extra argument place and definitive concept corresponding to the event or state (or whatever) described by the verb. Two examples of this are shown in figure 24. There is no treatment of tense or time in the system as it stands, but in theory, temporal information could be associated with these event and state concepts.

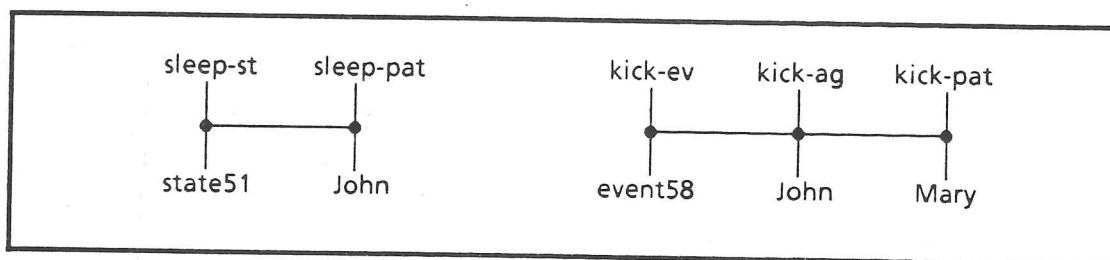


Figure 24: "John sleeps", "John kicked Mary"

5.6.3 Adjectives

Adjectives are seen as specifying states in much the same way as verbs can, and the d-link translation of an adjective predication looks very much like that of an intransitive verb (figure 25).

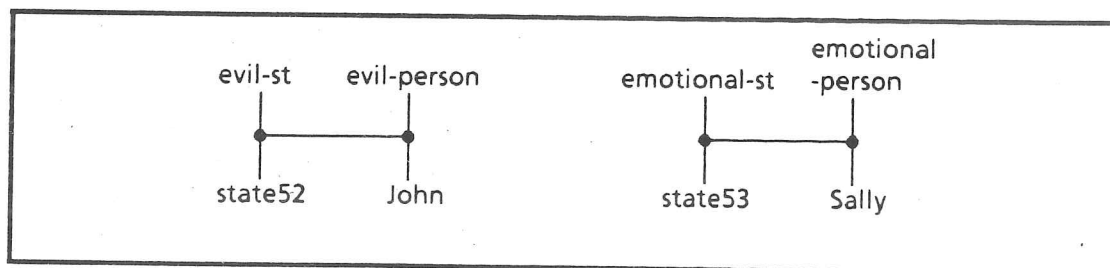


Figure 25: "John is evil", "Sally is emotional"

Note that there is a strong degree of uniformity in all these representations, and indeed it would probably be more consistent to include a state concept in the d-links arising from nouns, as shown in figure 26, where *man-st* is a definitive concept for 'the state of man being a man'. This would be a way of recognizing that, say, manhood is not an eternal condition, but the earlier representation without states is retained for simplicity.

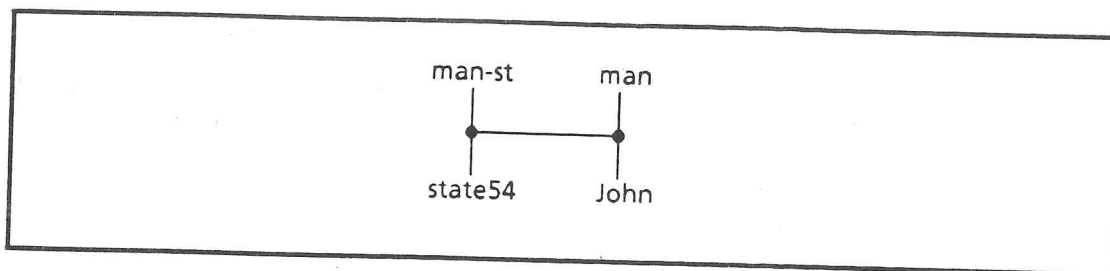


Figure 26: An alternative representation of "John is a man"

5.6.4 Event structure

As explained above, the representational idioms for both verbs and adjectives make reference to events and states. It turns out to be useful in the examples processed by MINT to employ a very simple idea of event structure, where an 'event' is seen to lead to a 'consequent state', and conversely, a 'state' is seen as resulting from an 'antecedent event'.¹⁵

Figure 27 shows how these ideas are used in relating the event of breaking and the state of being broken. This connection of broken-st to break-ev means that whenever a d-link is constructed for either an event of breaking or a state of being broken, there is an implicit reference in the network to a corresponding consequent state or antecedent event respectively. These implicit references can be exploited by MINT in language processing.

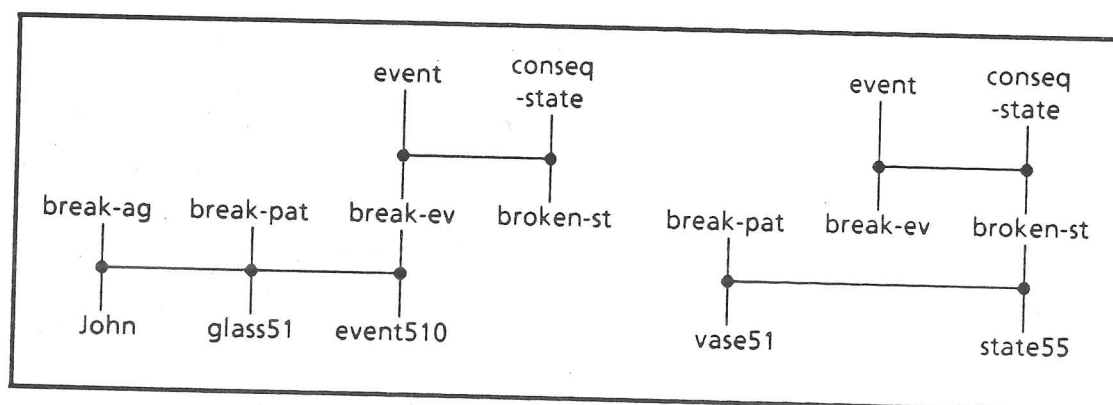


Figure 27: "John broke the glass", "The vase is broken"

5.6.5 Prepositional phrases

The range of examples tackled by MINT is greatly enhanced by the inclusion of a method of handling prepositional phrases in the input. These prepositional phrases are specified by the parser as attached to either a noun or an event, and are handled in MINT by matching

¹⁵ This event structure can be viewed as a much simplified version of that given in [Moens and Steedman 87]. There is no reason why a more sophisticated treatment could not be encoded in DREP, but the existing event / consequent state treatment is adequate for current purposes.

them to d-links in the network in just the same way as other input forms. This matching process is described in detail in the next chapter, the important point here is that the key to matching is the presence of d-links which specify how prepositional arguments attach to events (figure 28).

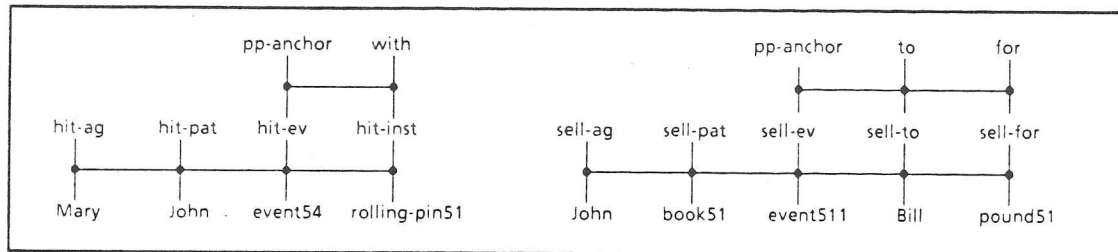


Figure 28: Attaching prepositional arguments to events

5.7 DREP as a knowledge representation

In the preceding sections of this chapter, it has been stated that DREP is not intended to be a general knowledge representation and yet much of the knowledge it encodes has very much the appearance of that represented in other more conventional frame / semantic net formalisms. The difference is that DREP is designed to represent *descriptive* knowledge; the reasoning licensed by DREP is reasoning about descriptions and in general reasoning is not expected to be literally valid. The knowledge represented in DREP is therefore very close to lexical semantic knowledge, a sort of intuitive knowledge as reflected in the use of language, rather than objective knowledge derived by scientific study. This is in line with the approaches adopted in the TACITUS system [Hobbs *et al.* 86], [Hobbs 87] and in Dahlgren's 'Naive Semantics' [Dahlgren *et al.* 89].

On the other hand, this lexical semantic knowledge is not totally divorced from reality – there would appear to be a good deal of overlap between this lexical knowledge and what is generally described as 'commonsense knowledge'. This is apparent in the 'frame interpretation' of DREP outlined above and no doubt I have already been guilty of inaccurately paraphrasing the representational content of DREP as commonsense knowledge rather than descriptive knowledge. This laxity is likely to continue – forever saying 'can be described as' is rather more cumbersome than the concise 'is a', but the distinction is always present and should be born in mind.

It is, then, meaningful to ask how DREP compares with conventional knowledge representation formalisms used in artificial intelligence in so far as they all represent 'commonsense' knowledge.

5.7.1 Representational power

When considering the expressive power of DREP, it is useful to translate the representations into a logical formulation, an operation which is relatively straightforward. This is done as follows:

Concepts translate directly as logical constants, for example John becomes John and man becomes man. Descriptions, on the other hand, translate as predications, so we have

```
MAN(man)
PERSON(person)
KICK(kick-ag, kick-pat, kick-ev)
HIT(hit-ag, hit-pat, hit-ev)
EVIL(evil-person, evil-st)
```

Notice that these are all intrinsic descriptions of definitive concepts.

D-links can be translated as analogy predications, but since a d-link can have any width, and there is no order of the maps within a d-link, it is best to consider the DLNK predicate as operating on a *set* of ordered pairs, for example

- (12) DLNK({{man, person}})
- (13) DLNK({{John, man}})
- (14) DLNK({{kick-ev, hit-ev}, {kick-ag, hit-ag}, {kick-pat, hit-pat}})

These analogies license the inheritance of descriptions, so we are entitled to say, for example,

```
MAN(John)
PERSON(man)
PERSON(John)
HIT(kick-ag, kick-pat, kick-ev)
```

This way of characterizing description inheritance in logical notation rapidly gets unwieldy, but a shortcut can be found by observing that because the descriptive predicate MAN, say, is fundamentally associated with the definitive concept man, if it is known that MAN(*x*) is a valid description of *x* then there must be an analogical relationship between *x* and man (along a chain of d-links, or the logical equivalent):

$$\forall x \text{ MAN}(x) \Rightarrow \text{DLNK}(\{\langle x, \text{man} \rangle\}).$$

Similar comments can be made for more complex descriptive predicates with more than one argument, so given KICK(*x*, *y*, *e*) we can assume

$$\text{DLNK}(\{\langle x, \text{kick-ag} \rangle, \langle y, \text{kick-pat} \rangle, \langle e, \text{kick-ev} \rangle\}).$$

With this observation, the d-links (12) and (14) above can be interpreted as follows:

$$\begin{aligned} \forall x \text{ MAN}(x) &\Rightarrow \text{PERSON}(x) \\ \forall x, y, e \text{ KICK}(x, y, e) &\Rightarrow \text{HIT}(x, y, e) \end{aligned}$$

To put (13) in this form, however, would entail inventing a predicate JOHN to be an intrinsic description of John:

$$\forall x \text{ JOHN}(x) \Rightarrow \text{MAN}(x).$$

This shorthand way of translating the knowledge represented in DREP into logical form is not truly representative, for example, it does not reflect the analogical mechanism very well (it does not acknowledge the rôle of definitive entities and the d-link mechanism is lost) and it depends on the existence of a descriptive predicate for each combination of entities. This last point leads to a very uncomfortable proliferation of predicates – for example it would be necessary to have a predicate HIT-WITH-INSTRUMENT to include references to hit-inst. Also, the logical notation suggests an inappropriate extensional semantics, whereas what is required is an *intensional* semantics with logical constants denoting, say, guises. Nevertheless, the logical formulation is useful in testing the *representational* power of DREP.

So far we have seen that knowledge of the form

$$\forall x P(x) \Rightarrow Q(x)$$

(where x is a tuple of variables) can be represented using one d-link, as shown in figure 29 where intrinsic descriptions are indicated on the diagram applying to the relevant concepts.¹⁶

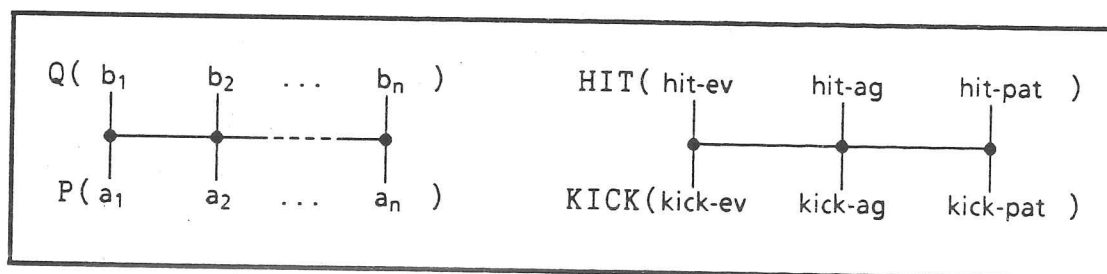


Figure 29: $\forall x P(x) \Rightarrow Q(x)$

From this it is easy to see how to represent the conjunction of consequents (figure 30).¹⁷ And similarly it is easy to represent disjunction in the antecedent (figure 31).

DREP can also express implications involving existential quantifiers in the consequent, though it must be born in mind that for DREP, existence does not mean real existence, but existence in a sort of Platonic universe of all imaginable (including impossible) things. An example of this is shown in figure 32 where concept evocation would be used to create the necessary concept during processing of a particular example of a grandparent - grandchild relationship.

¹⁶ Of course there are no variables in DREP, their place is taken by representative (definitive) concepts.

¹⁷ The vector notation x is retained, but it is not necessary for all variables to be used in all predications.

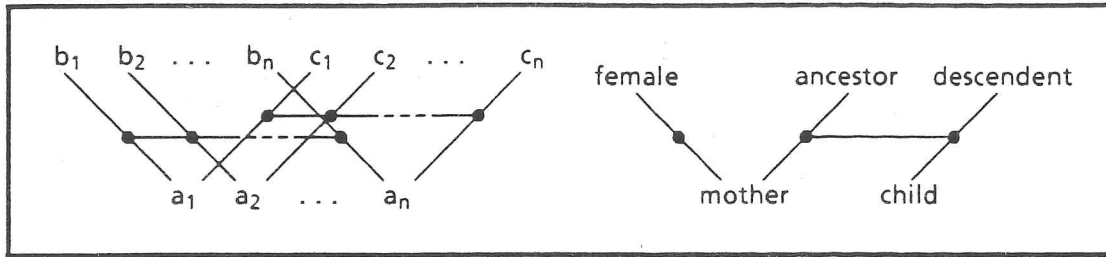


Figure 30: $\forall x P(x) \Rightarrow Q(x) \wedge R(x)$

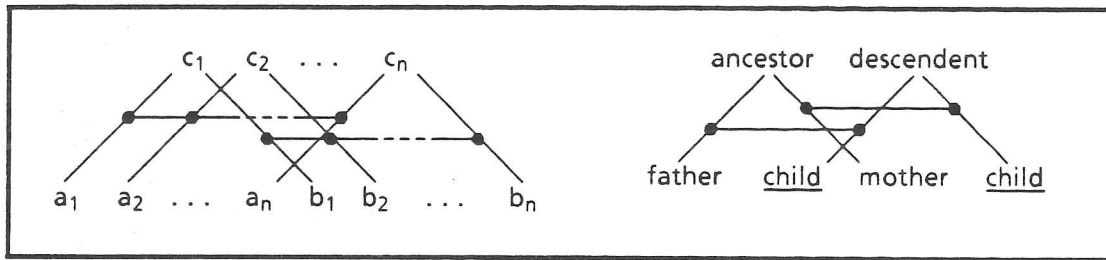


Figure 31: $\forall x P(x) \vee Q(x) \Rightarrow R(x)$

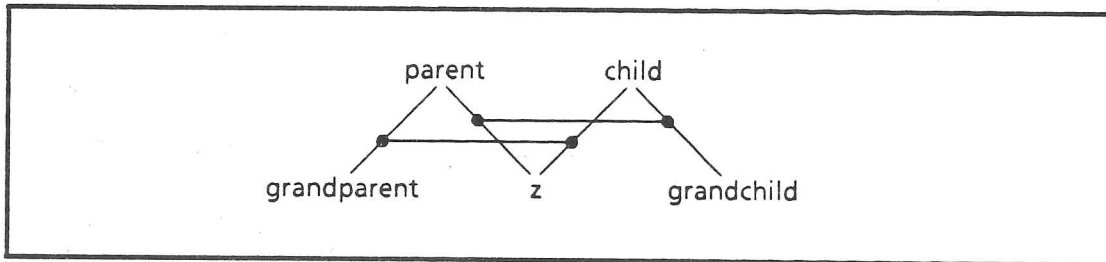


Figure 32: $\forall x, y \text{ GRANDPARENT}(x, y) \Rightarrow (\exists z \text{ PARENT}(x, z) \wedge \text{PARENT}(z, y))$

It is not, however, possible directly to represent disjunction in the consequent as in

$$\forall x P(x) \Rightarrow Q(x) \vee R(x)$$

$$\forall x, y \text{ PARENT}(x, y) \Rightarrow \text{MOTHER}(x, y) \vee \text{FATHER}(x, y)$$

and it is difficult to represent conjunction in the antecedent,¹⁸ as in

$$\forall x P(x) \wedge Q(x) \Rightarrow R(x)$$

$$\forall x, y \text{ PARENT}(x, y) \wedge \text{FEMALE}(x) \Rightarrow \text{MOTHER}(x, y).$$

Both of these involve going from more general to more specific descriptions, which is a general weakness of DREP *per se*, but is handled instead in MINT as part of the metaphor interpretation process.

¹⁸ There is in fact a method of representing conjunctions in the antecedent which involves the use of 'associated d-links' which are not discussed until the next chapter.

Another logical inadequacy in DREP is that negation receives no treatment – it is not possible, for instance, to represent

$$"\forall x \text{ MALE}(x) \Rightarrow \neg \text{FEMALE}(x) "$$

however, the knowledge represented in DREP is supposed to be close to natural language where negation is notoriously different from logical negation. Also, since DREP is intended to represent metaphorical as well as literal descriptions, it is probably as well to avoid the explicit denial of a description.

These shortcomings are not of great consequence in the MINT system. For one thing, much can be done using the representational power available – this representational power is, for example, broadly equivalent to the power in Hiyan Alshawi's MEMORY formalism [Alshawi 83, 87], which has been used successfully in his own database knowledge acquisition task and also in a project to develop a transportable natural language front end for database systems [Copestake and Sparck Jones 89]. Secondly, MINT is a system intended to be a preprocessor to supply literal input to an application system where more powerful reasoning might be done using a different representation.

5.7.2 Ontological promiscuity

DREP conforms well to the idea of ontological promiscuity put forward by Jerry Hobbs [Hobbs 85] where he proposes a logical notation suitable for discourse processing (actually employed in the TACITUS project [Hobbs *et al.* 86], [Hobbs 87]). He advocates two criteria for such a notation:

Criterion I: The notation should be as close to English as possible...

Criterion II: The notation should be syntactically simple.¹⁹

Hobbs goes on to recommend “multiplying kinds of entities, by allowing as an entity everything that can be referred to by a noun phrase” which is very much the idea of c-entities and therefore DREP concepts.

Hobbs's formalism, then, is a logical notation which shares many of the aims of DREP, and indeed looks roughly like the logical notation developed above. He too has event and state variables, intensional individuals, and impossible individuals. But with Hobbs's notation, in common with all logical formalisms, there would be significant problems when it came to implementing descriptonal analogy. Firstly, the emphasis on individuals is lost and so analogies become hard to represent and use. Secondly, and consequently, there would be the proliferation of predicates as outlined above – Hobbs already has two versions of each predicate, one with and one without the event (or state) variable, and more would follow for

¹⁹ [Hobbs 85] p. 61

different combinations of the arguments.

5.7.3 Semantic networks

DREP is more directly comparable to other semantic network formalisms, such as KRL [Bobrow and Winograd 77], KL-ONE [Brachman and Schmolze 85], and KODIAK [Wilensky 87]. It would not be appropriate here to go into detailed comparisons of DREP with these general knowledge representation formalisms, as their aims are rather different. There are, however, notable areas of similarity and difference which can be pointed out in general terms:

The knowledge represented

DREP is intended to represent descriptive knowledge, whereas the other formalisms discussed here generally seek to represent more concrete 'absolute' knowledge. This, however, is less of a difference than it might appear at first sight:

The primary concern of DREP is to represent how *descriptions* are inherited by one concept, or group of concepts, from another concept, or group of concepts. These descriptions may be 'metaphorical', and so in general will not be mutually consistent, if taken literally. The other representations, on the other hand, are primarily concerned with *properties* and how they are inherited – these properties are generally taken to represent 'objective' knowledge and are expected to be mutually consistent.²⁰ It would be possible to use DREP simply to represent property inheritance by equating descriptions with properties in the obvious way and banning all 'metaphorical' descriptions. DREP would still retain its analogical nature together with the concomitant advantages outlined below.

Frames

All these representations have a strong frame flavour to them, there is much talk of slot filling and rôle playing, and there is a strong idea of *structured inheritance*, that is, inheritance of relationships rather than simple lists of properties. Differences emerge, however, when considering the formal status of frames in the different representations; in general there has been a move away from the explicit recognition and handling of frames.

In KRL and KL-ONE the principal nodes in the networks corresponded directly to frames and consequently have a great deal of internal structure, KRL having the richer set of

²⁰ The notion of consistency is considerably complicated when dealing with 'default' properties and non-monotonic reasoning. See, for example, [Ginsberg 87]. Such issues are ignored here.

possibilities. KODIAK has a much weaker notion of frame in that its nodes have no internal structure, instead organizing nodes, 'owner' nodes, are related externally to other 'role' nodes representing their slots, so that the distinction between frames and slots becomes less visible, but it is there nonetheless. In DREP, by contrast, the notion of frame is completely implicit – all concepts have the same status, there is no owner concept and consequently no role-owner distinction. This is made possible by the use of definitive concepts which implicitly label the slots of implicit frames, as discussed earlier.

This move away from the explicit representation of frames to a more implicit approach has major advantages in terms of the flexibility of the resulting system: (a) Adding more detail to the representation often involves adding slots to frames (in DREP it would be done by adding and widening d-links), this becomes a neater operation whose consequences need only be felt locally, as there is no need for changes to be made wherever the frame is mentioned. (b) An often cited criticism of frames has been that they have a tendency to become too large and monolithic – as more and more detail is represented, the number of slots in a frame increases rapidly making the frame itself cumbersome to handle. By not handling the frame as a unit, the extra details are hidden until they are required, a phenomenon that might be regarded as an attitude of 'lazy evaluation'. (c) Incompleteness of knowledge in instances of a frame is handled more efficiently as it is simply ignored without the creation of large tracts of empty structure.

Complexity

Not unrelated to the movement away from a formal notion of frames is a decrease in complexity of the representations. KRL was enormously complex, being deliberately profligate in its provision of representational devices, which in the end saw KRL "collapsing perhaps under the weight of its own features".²¹ KL-ONE attempted to rationalize much of this representational machinery, but still, with all the internal structure of its nodes, had a very large array of different node and link types with special meaning to the system. In both these cases, much of the complexity arose out of a desire to cater for all requirements and to provide efficient built-in mechanisms for processing certain types of information. The result in both cases is a rather inhomogeneous representation. KODIAK attempted to do away with most of this inhomogeneity by reducing the number of node and link types and getting closer to the spirit of natural language, which seems to have a very uniform way of representing things, and does not seem to map very precisely onto the built-in ideas of, say, 'is a', 'and', 'or', and 'not' in artificial representations. But even KODIAK has a substantial complexity, particularly arising from its method of structured inheritance for frames, which

²¹ [Brachman and Levesque 85] p. 263

makes knowledge represented in the network difficult to follow.

Although it is not really fair to compare the complexity of DREP with those of the above representations, as DREP is markedly less ambitious in its representational aims, there have been significant savings in complexity as a result of the omission of explicit frame concepts and also with respect to instantiation as described below.

Instantiation

Instantiation is the area where DREP shows most difference from the more conventional semantic network representations mentioned above and this difference is a direct consequence of its semantics. Instantiation ('individuation' in KL-ONE) is the process of going from a generic individual to a specific individual – the Arc de Triomphe, for example, is an instance of the generic concept of an arch, and John is seen as an instance of the generic man. See, for example, [Brachman 83]. The process of instantiation is generally a source of complexity in semantic networks, for example in KL-ONE individuation leads to some duplication of representational machinery – one version for generic relationships and another for individuated relationships. In DREP, though, there is no notion of generic individual which has special meaning in the formalism – the rôle of the generic individual is typically played by a definitive concept, all concepts are deemed to be individuals and instead of links specifying that one is an instance of another links specify that one is analogous to another.

Generic individuals can, of course, be represented in a way that is meaningful to the user of the network, but which has no significance to DREP; this is done by modelling the instantiation relationship as unexceptional knowledge. For example, it is possible to represent set membership (a popular interpretation of individuation used in semantic networks) by use of the definitive concepts set and member. A set is then seen as an individual and its members are seen as more individuals standing in the same relation to the set as member to set (figure 33).

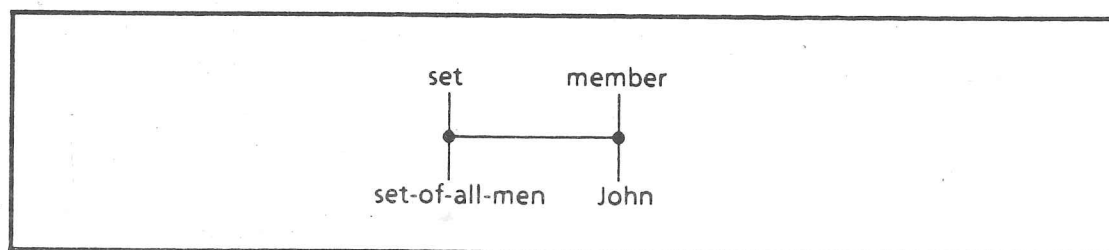


Figure 33: Representation of set membership

5.7.4 Summary

DREP is a fully intensional semantic network formalism which, though not fully logically adequate, is capable of representing usefully a significant range of 'commonsense' knowledge in a way that is simple and homogeneous. This knowledge is principally to do with lexical semantics. DREP can be seen as carrying through a notable trend in semantic network formalisms, having achieved a marked simplification over its predecessors. This simplicity can be put down to the absence of a formal idea of domains or frames (although there is a strong *implicit* idea of frame) and critically to the use of definitive concepts to play the part conventionally played by generic individuals.

5.8 The correspondence of d-links and descriptions

Up till now, this chapter has described DREP as a semantic net formalism which is capable of representing homogeneously many types of knowledge. This section is intended to outline how this knowledge is thought of in the MINT system and how it is particularly suited to the representation and interpretation of metaphors. The key point is that d-links represent analogies, and by virtue of the Principle of Descriptive Analogy, these analogies can be seen to correspond to *descriptions* of their targets.

This will be an important point to be born in mind when considering the major processing of MINT, and how it relates to the discussion in chapters 3 and 4 – the processing there was largely reasoning with *descriptions*, whereas the processing in MINT is achieved by reasoning with d-links. The correspondence between d-links and descriptions also underlies the representation of well-formedness conditions in MINT, namely the labelling of d-links as literal or metaphorical and the specification of argument restrictions. These issues too are outlined in this section.

5.8.1 D-links correspond to descriptions of their targets

A d-link represents an analogy, and so by the Principle of Descriptive Analogy it can also be seen as representing a description of its targets, namely the intrinsic description of its sources transformed by source replacement. For example, the intrinsic descriptions of the sources of the d-links in figure 34 are

- (15) (RISE "rise-pat" "rise-ev") and
- (16) (SEE "see-ag" "see-pat" "see-ev").

These can be transformed into descriptions of the targets by source replacement:

- (17) (RISE "soar-pat" "soar-ev") and

(18) (SEE "understand-ag" "understand-pat" "understand-ev")

and these are the descriptions corresponding to the two d-links.

Of course, there will not always be an intrinsic description of these sources given in the lexicon, but the idea can be carried through to all d-links by postulating for each combination of sources a description " $S_1 \dots S_n$ are related in such and such a way".²²

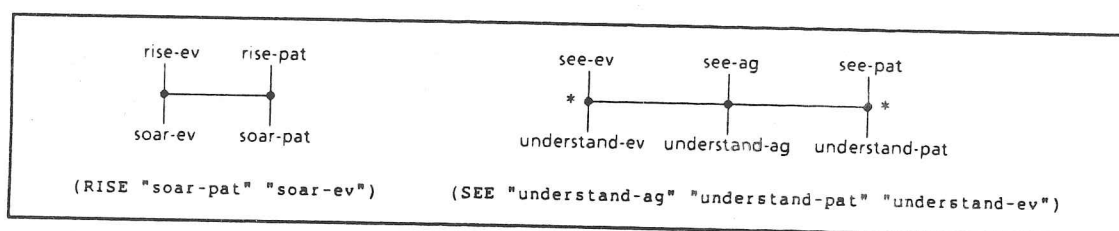


Figure 34: d-links representing descriptions

Literal and metaphorical d-links

The first of the above descriptions, (17), is deemed (by a notional dictionary) to be a *literal* description of the definitive concepts *soar-pat* and *soar-ev*, and so its d-link is labelled as 'literal'. (18), on the other hand, is deemed to be a metaphorical description of "understand-ag", "understand-pat", and "understand-ev", and so its d-link is labelled as 'metaphorical' (using the * notation).

It is important to note that these classifications of literal and metaphorical are not necessarily rooted in 'objective' fact, rather they are judgements about the use of *language* – a different dictionary might give the d-links different labels. This literal / metaphorical label on d-links should be seen as a 'feature' value – it does not alter the fact that *all* d-links represent analogies, it is simply a comment attached to the analogy by the dictionary saying whether the corresponding description is deemed literal or metaphorical. In fact, in MINT processing, this feature of d-links is ignored except when judging the well-formedness of descriptions.

Literal and metaphorical chains

Chains of d-links can also be seen as corresponding to descriptions, since when composed they yield composite d-links which specify descriptions in just the same way as simple d-links. Unlike simple d-links, however, these *chains* are not explicitly marked as either

²² This is not as ad hoc as it may at first appear: in practice, d-links only ever combine sources which are related in a straightforward way, since, under the frame interpretation, the sources of a d-link are always members of the same frame. The problem only arises when there is no *direct* linguistic way of expressing the relationship, as, for example, the relationship between *rise-ev*, *rise-pat*, and *rise-pat-ht*.

literal or metaphorical. Instead, their literal or metaphorical status can be deduced by considering the status of the component d-links – if these are all literal, then the composite d-link, and therefore the chain, is also literal. If, on the other hand, any one of the component d-links is marked as metaphorical, then the composite is also assumed to be metaphorical.

This latter assumption is really erring on the side of caution: it is quite possible that the description represented by the chain would be regarded as literal by the dictionary; the point is that the chain by itself gives no evidence of literalness. Figure 35 shows examples of literal and metaphorical chains.

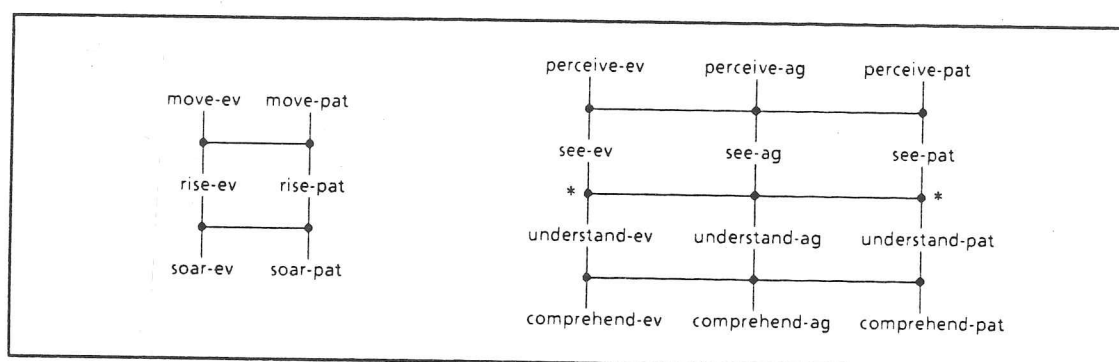


Figure 35: Literal and metaphorical chains

5.8.2 Well-formedness conditions

Well-formedness, as defined in chapter 3, was a condition which could hold of a description. The criteria for well-formedness in that implementation-independent theory were determined in an unspecified manner by the system's dictionary; the technique used in MINT is to specify these conditions within the DREP network itself through the interaction of 'argument restrictions' and the literal / metaphorical labelling of d-links described above. In this way, it is possible for MINT to judge whether an input description, or a new description generated internally, is well-formed.

Argument restrictions

The realization of well-formedness conditions in MINT depends on a development of the well established idea of 'argument restrictions', or 'verb preferences':²³ for a predication to be well-formed, its arguments must be of a certain 'sort'. For example, for the description (RISE "x" "e") (roughly "'e' is the event of 'x's rising") to be well-formed, it is

²³ See, for example [Wilks 75].

necessary for "x" to be a physical object and "e" to be an event.²⁴

Conventionally in natural language systems, sorts are specified in a separate 'sort hierarchy', but in DREP, this 'sort' hierarchy forms an integral part of the network, indistinguishable from any other type of knowledge represented. Instead of requiring that arguments *be* of a specified sort in some 'objective' sense, DREP requires that arguments be *literally describable* in specified ways. This confers an intuitively appealing consistency to the system in its rejection of the idea of 'objective' knowledge, and it enables sortal restrictions to be represented using d-links, in a way which is much more flexible than more conventional treatments – *any* DREP concepts may be used to specify argument restrictions, and restrictions may involve relationships between arguments. It also has the major advantage, when it comes to processing, that if an argument is found to be only *metaphorically* describable in the way specified by an argument restriction, the analogy underlying that metaphor can be used for further interpretation of the original description whose well-formedness was being established. This offers the key to MINT's handling of extended and systematic metaphor described in the next chapter.

I-links and p-links

In DREP, the arguments of predicates, and so also argument restrictions, are associated with definitive concepts. The restrictions are represented by d-links which have the definitive concepts as targets, and are marked as being of type 'p' ('p' for 'preference'). Most, if not all, of the d-links encountered so far have been of type 'i', and in future, when it is necessary to distinguish type 'i' and type 'p' d-links, they will be abbreviated to 'i-links' and 'p-links'. This type information should be regarded, like literalness, as a 'feature' attached to a d-link – p-links and i-links both represent analogies (and correspondingly descriptions), but are used slightly differently in processing.²⁵

Examples of p-links (dotted) representing the argument restrictions for RISE are shown in figure 36(a). Figure 36(a) also shows how these relate to the i-link representing (RISE "balloon51" "event53"). Composing the two chains (one for each p-link) yields two composite p-links²⁶ which specify the conditions required of balloon51 and event53 (figure 36(b)).

These composite p-links are used as templates for (complete) matching operations; if matching *literal* chains can be found, the original i-link is judged well-formed, (along with

²⁴ The restriction on "x" could be made tighter, perhaps a *mobile* physical object, but a plain physical object will do as a first approximation.

²⁵ One of the main differences is that p-links are 'invisible' to matching operations.

²⁶ A chain involving a p-link yields a composite p-link when composed.

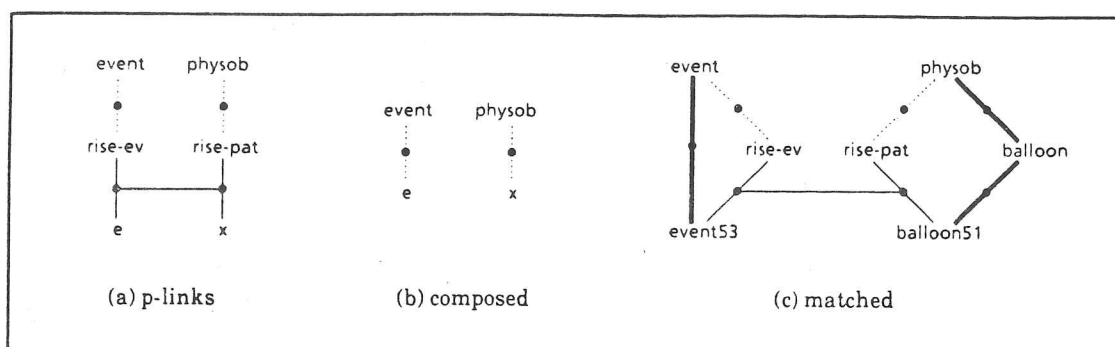


Figure 36: p-links specifying argument restrictions

the corresponding description), otherwise it is judged metaphorical.²⁷

The evaluation of (RISE "balloon51" "event53") as well-formed is shown in part (c) of the figure. The matching chains of literal i-links are emphasized; one is a direct link from event53 to event and the other is a chain linking balloon51 to physob via balloon. In descriptive terms, the two p-links specify that (RISE "balloon51" "event53") is well-formed if (PHYSOB "balloon51") and (EVENT "event53") are *known* literal descriptions. The matching operation reveals literal chains corresponding to just these descriptions, so the original description is indeed judged well-formed and the i-link marked as literal.²⁸

This is the most basic form of argument restriction, more complex forms are possible using wider p-links and these are of great importance in metaphorical interpretation, as hinted at earlier. This is perhaps most easily seen by considering the frame interpretation of DREP: rise-ev and rise-pat label slots in the 'rising' frame, and p-links specify well-formedness conditions for an instance of that frame, i.e., the filler of the rise-ev slot should be an event and the filler of the rise-pat slot should be a physical object. Now, the rising frame has more than just two slots, there is, for example, a third called rise-pat-ht which is to be filled by the height (in the sense of altitude, rather than tallness) of the filler of the rise-pat slot. An additional well-formedness condition on an instance of the rising frame is that the fillers of the rise-pat and rise-pat-ht slots should be related as a physical object to its height.²⁹ This complex well-formedness condition is easily represented in DREP by a width two p-link as shown in figure 37. For clarity, the p-link up from rise-ev has been omitted, and it should be noticed that the original well-formedness condition on rise-pat has been

²⁷ Recall the working assumption that ill-formedness is due only to metaphor.

²⁸ The apparent discrepancy between well-formedness and literalness here is due to the fact that at any given time the network represents a particular *interpretation* of an input. Well-formedness is actually judged relative to this interpretation, and so if a description is judged well-formed with respect to this interpretation, it can be regarded as intended literally in this interpretation. This point is dealt with further in the next chapter.

²⁹ Such complex argument restrictions would appear relatively rarely in English predications, as they require a certain redundancy in the expression, but an example might be "John gnashed his teeth", where there is a requirement that the agent and patient of this expression be related as a man to his teeth. It is, however, easy to come up with examples in artificial languages such as logical form, or frames.

subsumed by the new, wider p-link.³⁰

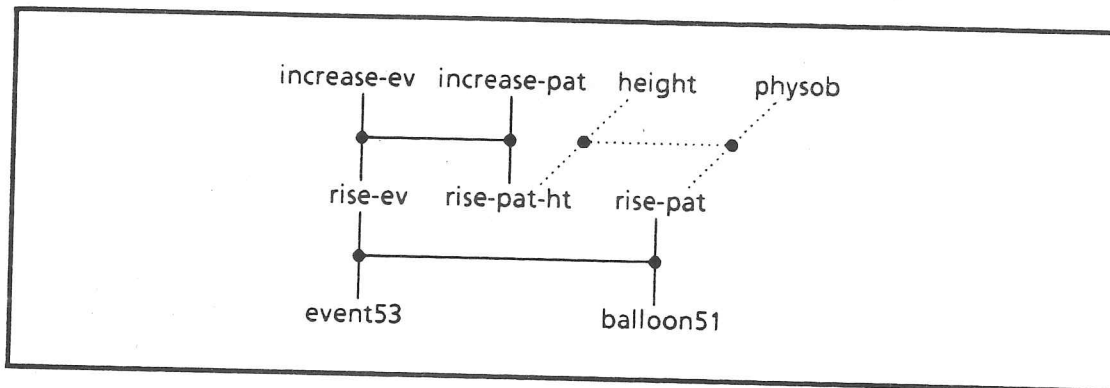


Figure 37: Complex well-formedness conditions

These wide p-links are used crucially in MINT to direct processing: continuing with the frame interpretation, input utterances lead to instances of frames which have only a limited number of their slots filled. Using p-links which specify how slot fillers are related to each other, it is possible to flesh out these initial frames by filling more of their slots, in a sort of reference resolution process. P-links are similarly used in *definite* reference resolution. These mechanisms are discussed fully in the next chapter.

5.9 Summary

This chapter has been an outline of the DREP knowledge representation formalism, which has been specifically designed to cater for the needs of descriptonal analogy and which forms the heart of the MINT system.

Noteworthy features of DREP are:

- (1) DREP is a fully intensional, homogeneous semantic network. It can be given a natural intensional semantics in terms of guise theory.
- (2) There is just one sort of node, called a 'concept', which represents intensional individuals, i.e., the c-entities of descriptonal analogy.
- (3) Some concepts (those corresponding to definitive entities) are associated directly with the lexicon, and this constitutes the interface between DREP and the 'outside world'.
- (4) There is just one basic sort of link, the 'd-link', which is used to represent analogies between c-entities.

³⁰ It should also be noticed that the piece of network shown in figure 37 encodes the dictionary-like knowledge that rising implies an increase in height.

- (5) Basic operations on DREP structures are composition of chains, widening of d-links, and matching of templates.
- (6) DREP is intended to represent descriptive knowledge and description inheritance, but could equally well be used to represent conventional properties and property inheritance while retaining its analogical semantics.
- (7) Because of the interpretation of d-links as specifying analogies between individuals, there is no need to have 'instantiation' links. This results in significant simplification over other semantic network formalisms.
- (8) DREP supports multiple perspectives.
- (9) There is no formal notion of domain in DREP, but there is an implicit, and very flexible, notion of frame: concepts can be seen as labelling the slots of frames.
- (10) The knowledge represented in DREP is intended to be broad and shallow: it is intended to represent *descriptive* knowledge, in other words, lexical semantics extended to cover metaphor.
- (11) There is no essential difference made between 'literal' and 'metaphorical' knowledge – all knowledge is represented in the form of analogies.
- (12) DREP is ideally suited for descriptive analogy as analogies are represented in a way that is both natural and cheap. This is why it is used in preference to existing formalisms, and in particular, logical form.
- (13) The analogies of DREP can be seen to correspond to descriptions of their targets.

6. MINT

This chapter describes the MINT system, a Lisp system capable of metaphorical interpretation using the principles of descriptonal analogy and having at its heart the DREP semantic network.

Overview

6.1 is a general overview of the MINT system. 6.2 describes the logical form used as input to MINT, how it is converted to DREP structures, and how initial reference resolution is done. 6.3 describes the main process of 'redescription'. 6.4 shows how redescription is used to interpret metaphors by abstraction and metaphorical reference resolution. 6.4 describes the process of 'construal', which effects generalized metaphorical reference resolution. 6.5 covers the last of MINT's three major interpretive processes – 'consolidation'. 6.6 describes how MINT handles multiple interpretations of input utterances. Finally, 6.7 describes MINT's overall control mechanism and gives a detailed example of metaphor interpretation.

6.1 Overview of MINT

The MINT system described in this thesis and implemented as a computer program in Common Lisp is not a complete system in itself. Figure 38 shows an overall view of how MINT is envisaged in its rôle as a component of a more comprehensive natural language processing system.

The figure shows the system divided into three major components as follows. Firstly there is a simple 'naïve' parser which takes English utterances and converts them into logical form with minimal semantic processing. Metaphorical utterances are taken at face value, producing, in general, semantically ill-formed logical translations. Secondly there is a pre-processing component which takes naïve logical forms from the parser and attempts to interpret them by performing reference resolution, and by producing a literal paraphrase (in logical form) which will be meaningful to the third and final component: the application. This application might be, for example, a database front end, or an expert system.

As an example of this line of processing consider the following simplified example "Inflation is rising". The naïve parser would produce a face-value translation of this as the logical form¹

¹ This logical notation is described fully in due course.

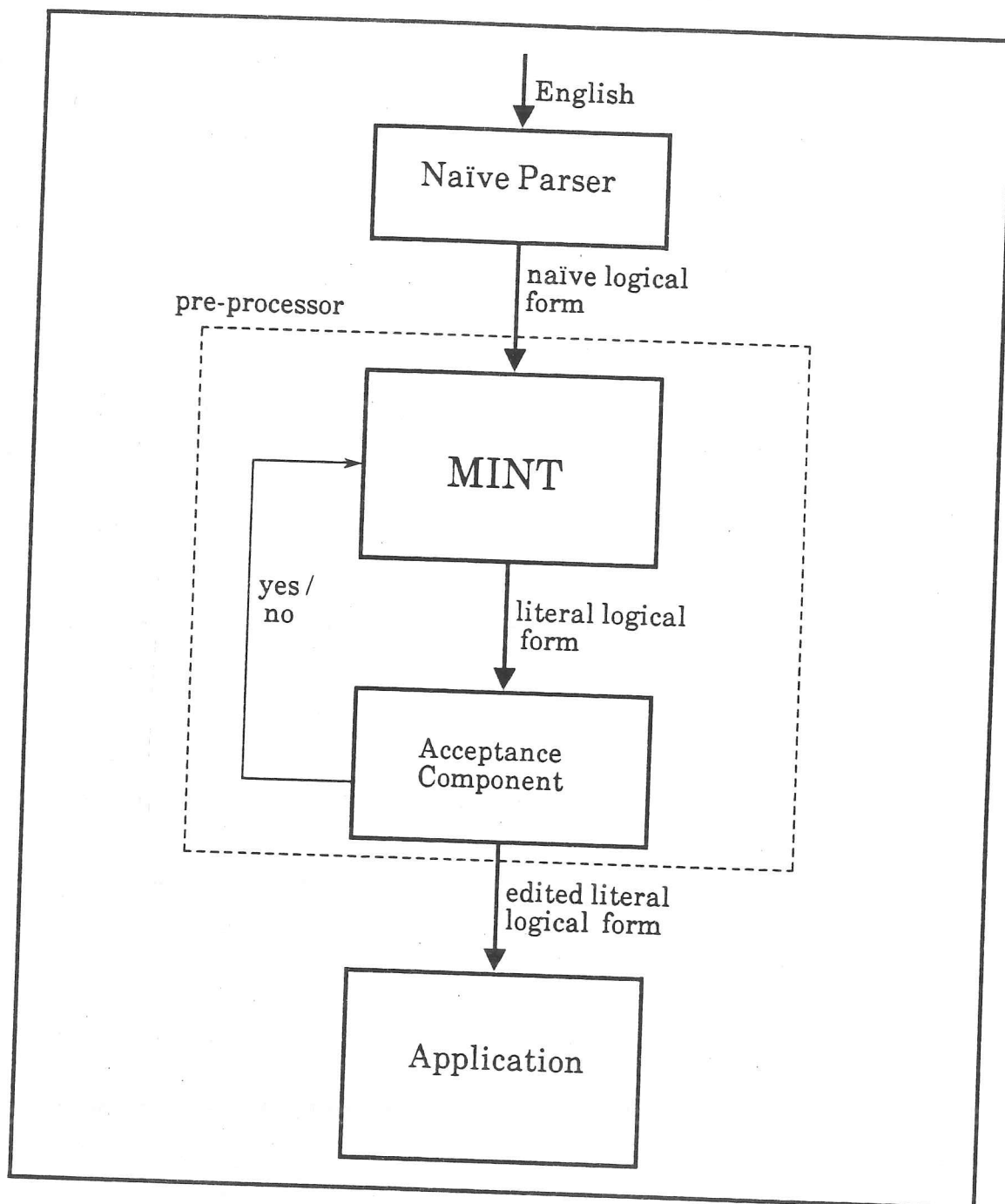


Figure 38: MINT in a Natural Language Processing system

- (1) (RISE "inflation" "sk-1") (EVENT "sk-1").

Given the assumption that the 'core' literal sense of RISE is physical rising of physical objects, the output of the parser would be meaningless to an application which has knowledge only of core senses. It is MINT's task to transform this input into a paraphrase which is meaningful to the application, namely

- (2) (INCREASE "inflation" "event0") (EVENT "event0").

This logical paraphrase would then be used by the application for its own ends.

The pre-processor is shown in the figure as being divided into two components: MINT and the Acceptance Component. The function of the Acceptance component is twofold. Firstly, it decides between competing interpretations thrown up by MINT, on pragmatic and deep semantic grounds. Secondly, it acts as a deep semantic filter on the chosen paraphrase by rejecting portions of the paraphrase at odds with the Acceptance Component's deeper knowledge of the subject area in hand. This second rôle of the Acceptance Component is required because of MINT's assumed broad and shallow knowledge base – MINT has to cope with metaphors which might have sources in many domains, whereas the Acceptance Component could be a great deal more specialized. Given this specialized knowledge, MINT could achieve the semantic filtering functions internally.

In this project, the presence of the parser and the acceptance mechanism are simulated. Implementing the parser could be done using existing technology (in fact the logical form was modelled on the output from an existing parser), but the acceptance mechanism with its deep semantic and pragmatic processing is beyond the current state of the art.

This breakdown of processing has been devised to enable MINT to operate as a realistic, manageably sized, and self-contained component of the whole system. There would of course be advantages in a greater integration of all the components, such as in the sharing of knowledge bases, but the illustrated structure allows attention to be focused on the business of producing literal paraphrases from metaphorical inputs.

6.1.1 The internal structure of MINT

Figure 39 shows a schematic expansion of the box labelled MINT in figure 38. The various functional components of this diagram are described briefly here and in greater depth in subsequent sections of this chapter. As can be seen, all these stages of processing involve reference to and manipulation of 'the network', which encodes both background knowledge (commonsense and dictionary-like knowledge) and input knowledge.

Network building

The principal input to MINT is a naïve logical form representation of the input utterance. This input is firstly converted into a number of concepts and d-links by reference to a simple lexicon containing translation rules for each logical predicate.² The DREP structures

² The 'lexicon' contains only rules for translating logical forms into DREP structures. The semantic definitions of words (predicates), and the well-formedness criteria alluded to in chapter 3 are stored in the network.

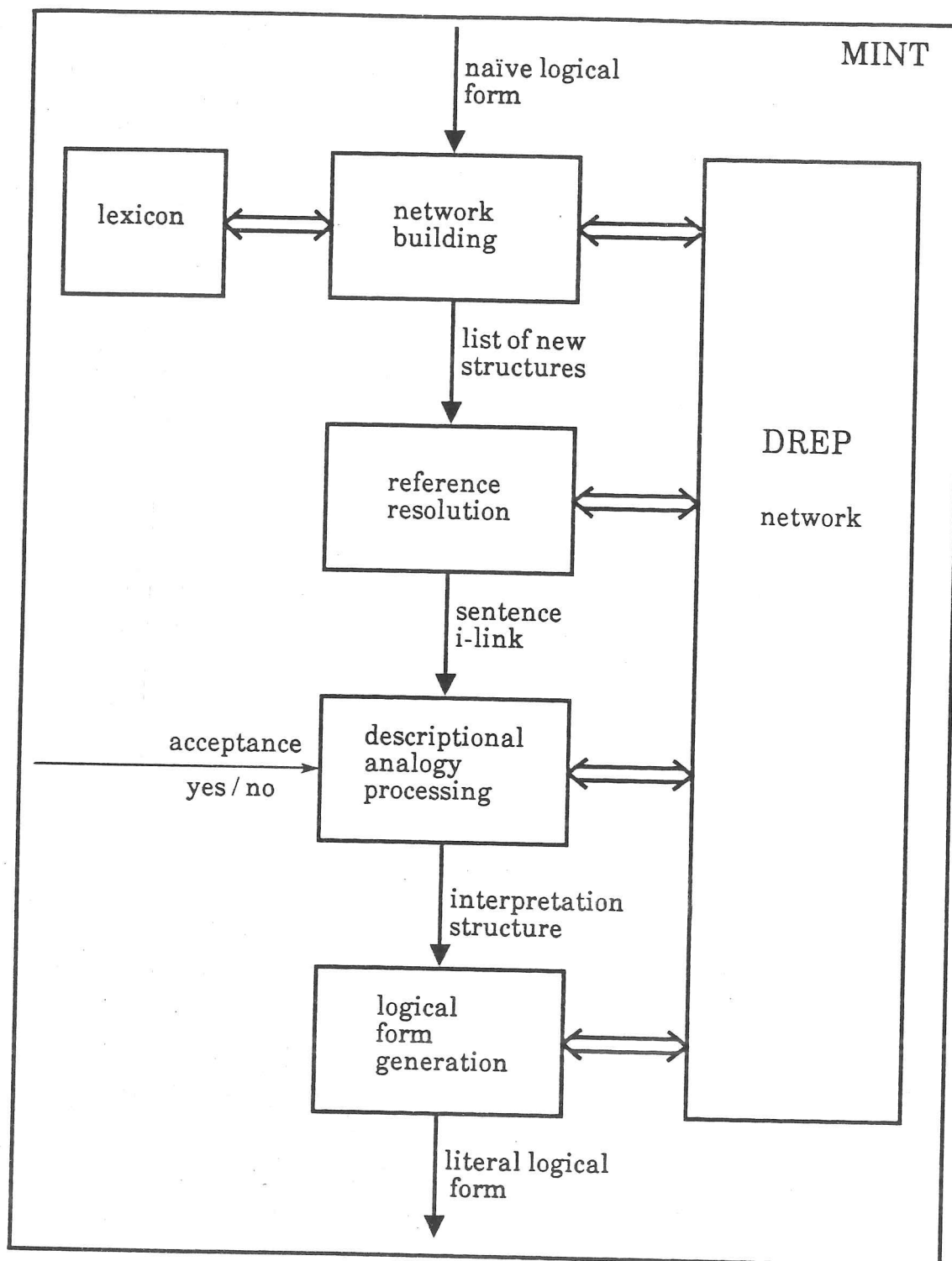


Figure 39: MINT

generated by this phase of processing are immediately incorporated into the network.

Reference resolution

The next phase considers these new DREP structures and performs simple reference resolution by matching definite descriptions of entities against descriptions of previously encountered discourse referents, as they are represented in the network.³ Reference resolution is achieved in a number of stages, roughly according to the complexity of the reference – for example the DREP representation of “the man” is resolved before relational referents such as “the man’s mother”. Indeed, the most complex reference resolution is achieved as a by-product of the next phase of processing – descriptive analogy processing. This is unsurprising, as both phases involve processing descriptions of entities.

Descriptive analogy processing

The output from reference resolution is a single ‘sentence i-link’, which links resolved references (and newly created concepts corresponding to the indefinite entities in the input) to the rest of the network. This sentence d-link is then used as the initial item on an agenda of chains to be considered in the next and principal phase of processing.

Each chain on this agenda is considered as representing a description of its target entities, and is matched against the rest of the network in an attempt to detect and interpret the use of metaphorical descriptions using the three basic techniques of ‘redescription’, ‘consolidation’, and ‘construal’. This procedure continues recursively until the agenda is exhausted.

If during one of the matching operations more than one match is found, then processing branches, each branch corresponding to a different interpretation of the input. What is judged heuristically to be the most likely branch is pursued first, until a satisfactory set of literal descriptions is reached. The result is an ‘interpretation’ structure, which is passed to the (simulated) Acceptance Component after translation back to logical form. If the interpretation is accepted, processing ceases. If not, processing backtracks to follow an alternative branch, corresponding to an alternative interpretation.

Logical form generation

The output of the descriptive analogy processing phase is an interpretation structure, which is principally a list of d-links corresponding to descriptions of the entities mentioned in the input. These descriptions are filtered to pick out those that are literal according to the

³ Actually, it is not necessary for definite entities to be discourse referents (entities that have cropped up in previous input) – it is enough that they should be identifiable.

interpretation, and converted into literal logical form notation in a straightforward reversal of the network building operation at the start of MINT's processing.

The overall operation of MINT, then, is to generate many descriptions of the input concepts, passing on those which it judges to be literal with respect to a particular interpretation, thus forming a literal paraphrase of the input utterance.

6.2 Network building and reference resolution

This section describes how input naïve logical forms are converted by MINT into their DREP representations. But first, it is necessary to give a brief description of the nature of this logical form.

6.2.1 Logical form

The logical form notation delivered by the notional parser to MINT is a fairly straightforward and standard representation of English, and is not so different from (although much simpler than), for example, the intermediate logical forms handled in SRI's Core Language Engine [Alshaw *et al.* 89], particularly in regard to the treatment of event and state variables and definiteness. One outstanding difference though, is that the naïve logical form used as input to MINT does not distinguish between polysemous word senses – it is very uncritical in that minimal semantic considerations are seen as having been applied during the parsing process, and as a result the metaphorical use of English words is preserved as either semantically ill-formed predications or well-formed predications not intended literally. It is MINT's task to perform the disambiguation of metaphorical word senses.⁴ This logical form is capable of representing simple declarative sentences, including simple adjectives, adverbs, and prepositions, but tense is ignored.

The logical forms used by MINT, both naïve and literal, are written as Lisp lists; predicates are written as Lisp atoms, constants are written as strings, and predications are written as lists, with the predicate and arguments within parentheses, as, for example, in (TALL "John").

There are no variables in this notation: the logical forms are seen as having been skolemized, that is, existentially quantified variables have been replaced by skolem constants, typically written "sk-N". For example, "a poem" is rendered as (POEM "sk-1"), rather than $\exists x$ (POEM x). Universally quantified variables are not considered.

⁴ In accordance with the simplifying assumptions made in this work, word senses arising by mechanisms other than metaphor or abstraction are not considered.

The simplest logical form representation is accorded to proper nouns, which are rendered as logical constants. "John", for example becomes "John". A similar treatment is given for mass nouns and bare plurals, so "eggs" becomes "eggs" and "water" becomes "water".

Common nouns, as has already been seen, are represented as predications, as are predicate nominals. For example, "John is a man" is represented as

- (3) (MAN "John").

The situation is a little more complicated for relational nouns, where the higher order predicate OF is used. For example, "the price of eggs" and "John's mother" are rendered as

- (4) (OF "sk-2" "eggs" PRICE) (PRICE "sk-2")
 (5) (OF "sk-3" "John" MOTHER) (MOTHER "sk-3")

where "sk-2" and "sk-3" are suitable skolem constants, and there is implicit conjunction between predications. The second conjunct in each of these is perhaps redundant, but they are there to represent explicitly that "'sk-2" is a price" and "'sk-3" is a mother", both of which are only implicit in the first conjuncts.⁵

Adjectives and verbs both give rise to predications involving state or event variables (following Davidson [Davidson 67]): "John sleeps", "John is tall", and "John hit Mary" are represented as

- (6) (SLEEP "John" "sk-4") (STATE "sk-4")
 (7) (TALL "John" "sk-5") (STATE "sk-5")
 (8) (HIT "John" "Mary" "sk-6") (EVENT "sk-6")

Note the convention that event and state variables appear in the final argument place.

These event and state variables could be used as a handle on predications allowing the representation of tense information, but this is not done in this project. They are, however, used to attach adverbs, for example "John slept fitfully"

- (9) (SLEEP "John" "sk-4") (STATE "sk-4") (FITFUL "sk-4")

and also prepositional arguments; for example, "Mary hit John with a rolling pin" is translated as

- (10) (HIT "Mary" "John" "sk-7") (EVENT "sk-7")
 (ROLLING-PIN "sk-8") (WITH "sk-8" "sk-7")

This attachment of prepositional arguments via event variables is imperfect and should not be regarded as a theoretical commitment – it is simply a convenient way of handling such arguments.

⁵ This apparent redundancy is inherited from the parser on which this was modelled.

There is an inherent problem in logical form in that predicates require fixed numbers of arguments, this problem manifests itself when verbs can be used with variable numbers of objects, i.e., ditransitively, transitively, or intransitively. One solution would be to create two versions of a predicate with differing numbers of arguments, but the solution adopted in MINT's logical form is to use dummy argument fillers. For example, "Bill paid a pound" and "Bill paid John a pound" are represented as follows:

- (11) (PAY "Bill" =dummy= "sk-9" "sk-10")
(EVENT "sk-10") (POUND "sk-9")
- (12) (PAY "Bill" "John" "sk-11" "sk-12")
(EVENT "sk-12") (POUND "sk-11")

A similar situation arises during passivization, where the subject of the active sentence is omitted in the passive form. These dummy arguments are discarded on translation into DREP structures.

Definiteness and indefiniteness

So far no distinction has been made between indefinite expressions and definite expressions, for example, the distinction between "a man" and "the man". In MINT, this distinction is seen as one between known and unknown predications (although this knowledge need only be implicit). Hence the logical form is split into two parts, one labelled as indefinite, which conveys new⁶ information, and the other labelled as definite, which conveys known or accessible information. For example, "a man" and "the man" both translate as (MAN "sk-13"), but in the former case the predicate is labelled as indefinite, whereas in the latter it is labelled as definite. This treatment is not unlike, for example, the use of a-term in the Core Language Engine [Alshawhi *et al.* 89] (the main difference being that here, logical forms are skolemized).

The motivation behind this labelling of predications, rather than entities, is that only a certain subset of the attributes of entities in an utterance are assumed to be known. Consider, for example

- (13) *The man snored.*

Here there is mention of two entities, the man and the event of his snoring. The fact that the former is a man is known information, and the fact that he snored is new information. In MINT's naïve logical form, (13) is represented as

⁶ The use of the word 'new' here should not be confused with the somewhat misleading psychological term 'new' meaning roughly 'not uppermost in the hearer's mind'. See for example [Chafe 76].

- (14) definite: (MAN "sk-13")
 indefinite: (SNORE "sk-13" "sk-14")
 (EVENT "sk-14")

which is to be contrasted with the representation of the sentence

- (15) *A man snored,*

namely,

- (16) definite: —
 indefinite: (SNORE "sk-13" "sk-14")
 (MAN "sk-13") (EVENT "sk-14")

The fact that "sk-13" appears within a definite predication in (14) is what tells the reference resolution component to attempt to identify it with an entity already encountered, and because (MAN "sk-13") is labelled as definite, *this* description is used to find the correct referent. The forms labelled as indefinite are assumed to be new information and so not matched against the existing network, for example, it is not expected that (SNORE "sk-13" "sk-14") would play any part in identifying the referent of "sk-13". Entities mentioned *only* in indefinite predications, such as the referent of "sk-14", are assumed new and so new discourse entities (with more mnemonic names) are created for them.

This is only a sketch of the reference resolution process, more detail is given later in this section.

More complex definite descriptions can also be accommodated in this scheme, for example,

- (17) *The man's mother died*
 (18) *The rabbit in the hat is white*

are represented as follows:

- definite: (OF "sk-15" "sk-16" MOTHER)
 (MOTHER "sk-15") (MAN "sk-16")
 indefinite: (DIE "sk-15" "sk-17")
 (EVENT "sk-17")

- definite: (RABBIT "sk-18") (HAT "sk-19")
 (IN "sk-18" "sk-19")
 indefinite: (WHITE "sk-19" "sk-20")
 (STATE "sk-20")

Two points come out in these latest examples. The first is that referents of definite descriptions are not necessarily discourse entities, i.e., entities that have been encountered in previous input – the man's mother need not be a previously encountered discourse entity, it is enough that the man is.⁷ The second point is that referents need not be unique under all of

⁷ This is in agreement with Chafe's view of definiteness – that definite descriptions indicate identifiable entities, not just discourse entities [Chafe 76].

their descriptions (there may be more than one rabbit and more than one hat, resolution should work as long as there is only one rabbit that is in a hat).

6.2.2 Translation to network structures

MINT's first step in processing its logical form input is to translate it into DREP notation. This translation is achieved by taking each conjunct in turn and comparing it with entries for its predicate in the system's lexicon. Each of these entries takes the form of a rule whose left hand side unifies⁸ with a predication, and whose right hand side uses the results of the unification to specify a corresponding d-link.

A simple example of such a rule would be that for the predicate MAN shown in figure 40, together with an example of its use. Here (MAN "sk-1") unifies with (MAN ?x) (with the variable ?x being bound to "sk-1"); the variable binding is then used in the generation of the width one d-link, where it has been coerced into a DREP concept of the same name.

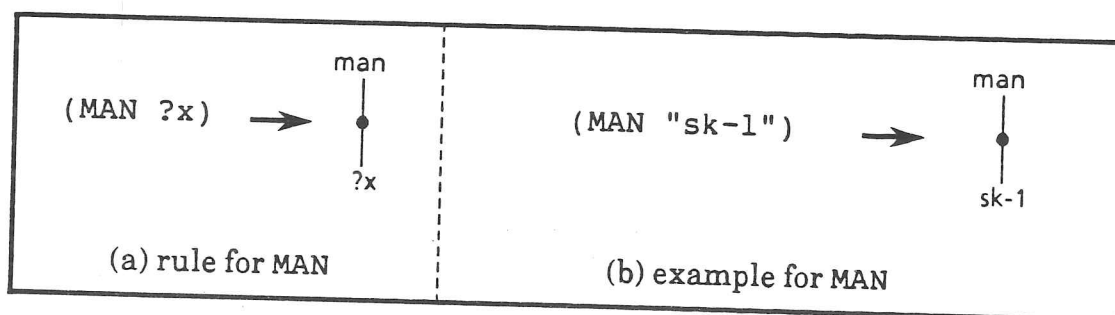


Figure 40: Translation rule for MAN

A more complex example would be the rule for KICK as shown in figure 41. Note that the variables used are given mnemonic names, but a similar disclaimer to that for concept naming must be given: ?subj does not necessarily correspond to the subject of the English sentence input (it would not be the case if, for example, the original sentence had been in the passive voice). These variable names, like concept names, are generated semi-automatically and are of no significance in processing.

The unification mechanism is exploited to the full in the case of OF, where many translation rules are given. Given a particular input predication, only one of these rules will actually unify with it. Two such rules for OF are shown in figure 42.

⁸ See for example [Charniak *et al.* 80].

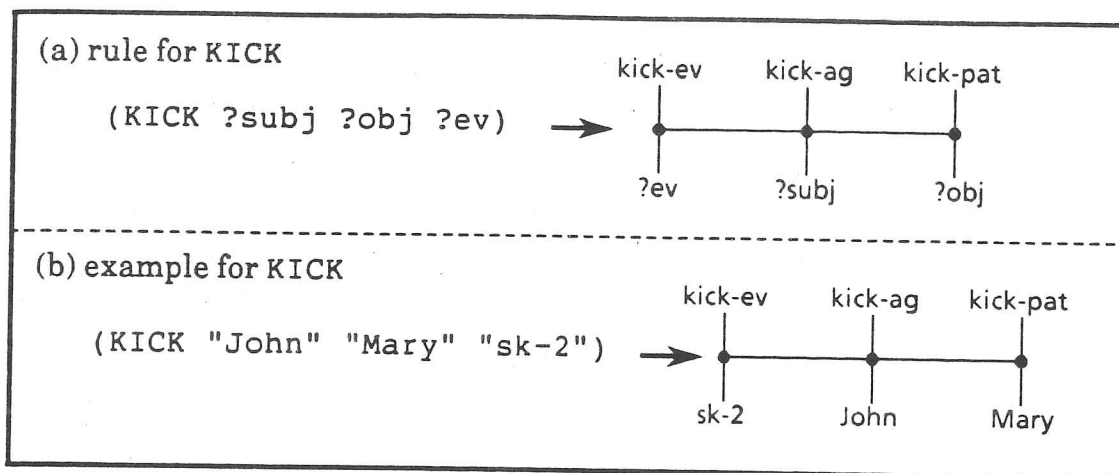


Figure 41: Translation rule for KICK

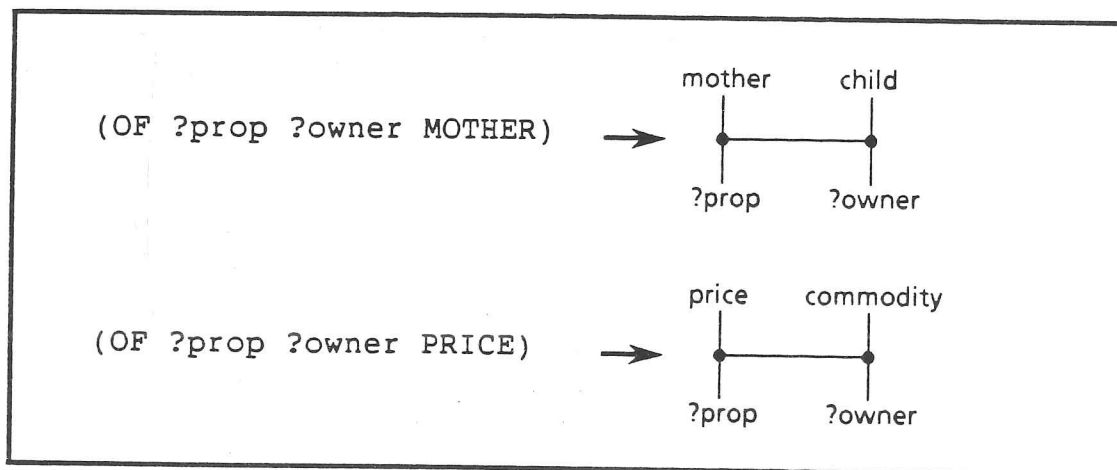


Figure 42: Translation rules for OF

Dummy arguments

It was seen above how some predications involved dummy argument fillers where, for example, the subject of a predicate was missing as a result of passivization or an object was missing where a verb was used intransitively. These dummy arguments give rise to maps with dummy targets during translation, and such maps are removed before any further processing occurs (to avoid possible conflict with the correct filler of that argument). Figure 43 shows this dummy map removal for the translation of "John was hit".

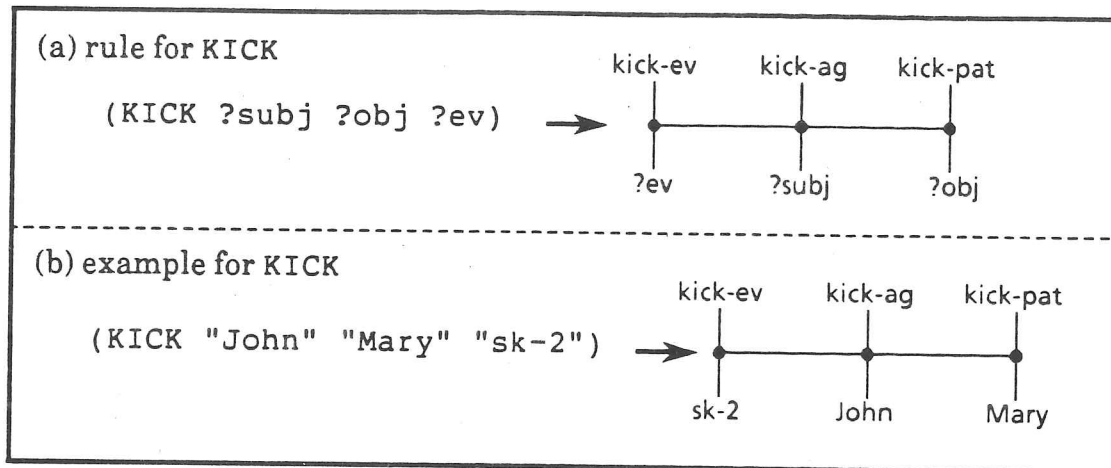


Figure 41: Translation rule for KICK

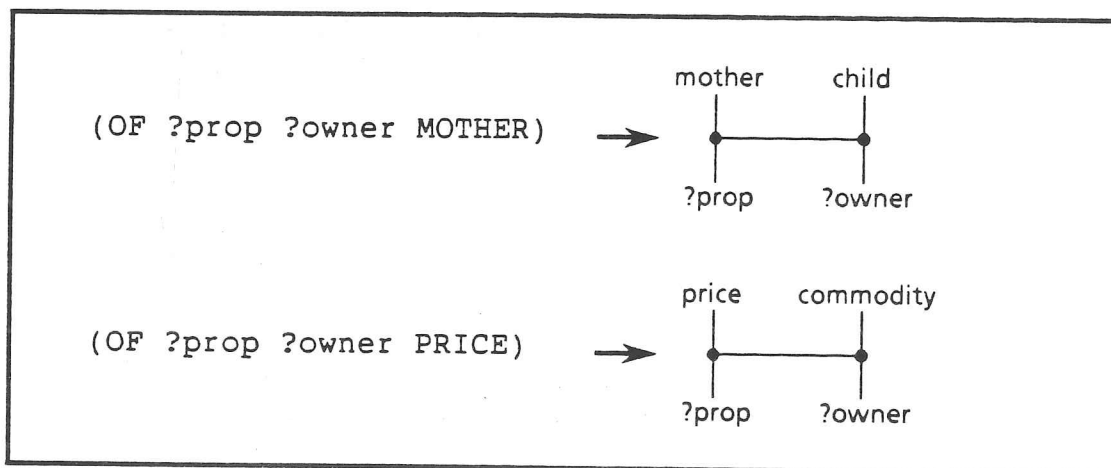


Figure 42: Translation rules for OF

Dummy arguments

It was seen above how some predications involved dummy argument fillers where, for example, the subject of a predicate was missing as a result of passivization or an object was missing where a verb was used intransitively. These dummy arguments give rise to maps with dummy targets during translation, and such maps are removed before any further processing occurs (to avoid possible conflict with the correct filler of that argument). Figure 43 shows this dummy map removal for the translation of "John was hit".

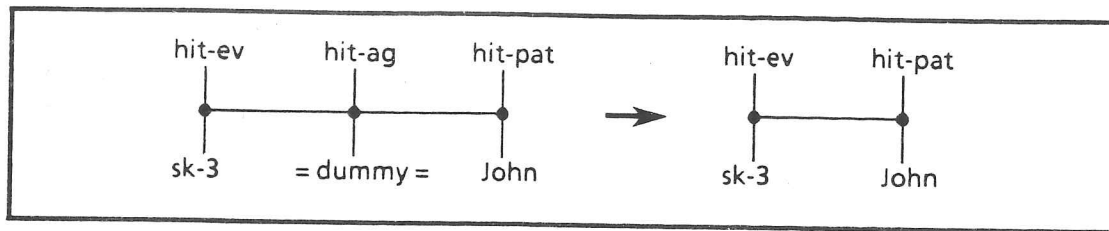


Figure 43: Dummy map removal

Amalgamation of d-links

The result of applying these translation rules, then, is a collection of d-links. It is possible that there is some duplication of information in these d-links, and this is removed by 'amalgamating' those d-links which 'overlap' (those that have maps in common). This situation tends to arise with OF predications and with multiple prepositional attachment. Figure 44 shows the results of amalgamation after translation of the following predications: (the common maps are emphasized)

- (19) *John's mother:*
 (OF "sk-3" "John" MOTHER) (MOTHER sk-3")
- (20) *John gave a pound to Bill for a book:*
 (GIVE "John" "=dummy=" "sk-4" "sk-5")
 (EVENT "sk-5") (POUND "sk-4") (BOOK "sk-6")
 (TO "Bill" "sk-5") (FOR "sk-6" "sk-5")

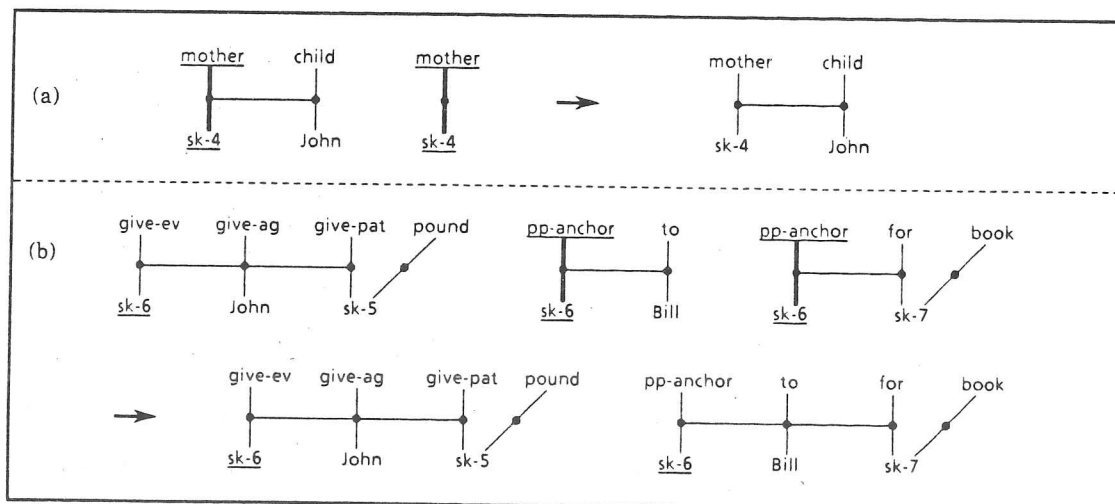


Figure 44: Amalgamation of d-links

6.2.3 Indefinite vs. definite predications

Both indefinite and definite predications are translated as d-links as outlined above, but the d-links arising from definite predications are marked as being of type 'p' (p-links). Indefinite

predications result in type 'i' d-links (i-links). The different ways in which these are used in reference resolution are discussed later in this chapter. This use of i-links and p-links fits in with the philosophy underlying their use for representing (complex) argument restrictions – i-links represent novel information, whereas p-links represent known information, i.e., information to be matched against the rest of the network – this is exactly the distinction made between indefinite and definite predications.

An example of the use of i-links and p-links in the representation of input utterances is shown in figure 45, where p-links, as before, are dotted. This is the d-link representation of

(21) *The man's mother died,*

which has the logical form:

```
indefinite: (DIE "sk-15" "sk-17") (EVENT "sk-17")
definite:   (OF "sk-15" "sk-16" MOTHER)
            (MOTHER "sk-15") (MAN "sk-16")
```

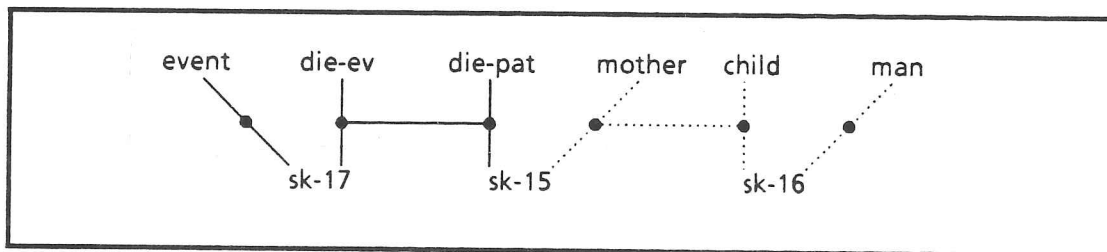


Figure 45: "The man's mother died"

6.2.4 Reference resolution

MINT has a basic ability to resolve references in its input, an ability which is sufficient to cope with a 'discourse' consisting of a few sentences. The resolution process will not be described in any detail here, apart from two features of interest: its methods of dealing with metaphorical and relational references.

The input to the reference resolution component of the MINT system is a collection of i-links and p-links, the former corresponding to indefinite predications and the latter to definite predications. The overall action of reference resolution is to set up a 'sentence i-link' which has the concepts mentioned in the input d-links as sources and their resolved referent concepts as corresponding targets. New concepts with unique mnemonic names are created to serve as the referents of indefinite entities.

Figure 46 shows the sentence i-link (emphasized) arising from the input

(22) *The red balloon is rising*

whose logical form is

```
indefinite: (RISE "sk-1" "sk-2") (EVENT "sk-2")
definite:  (BALLOON "sk-1") (RED "sk-1" "sk-3")
           (STATE "sk-3")
```

Here, the definite entities "sk-1" and "sk-3" have been resolved by looking in the network for discourse entities (concepts previously used in the current discourse) which can be described in the appropriate ways (i.e., which are the targets of chains to the source concepts indicated by the p-links). A new concept, event616, has been created to be the referent of the indefinite entity "sk-2".

P-links used successfully in the identification of definite referents are deleted from the network, as they have no further part to play in processing.

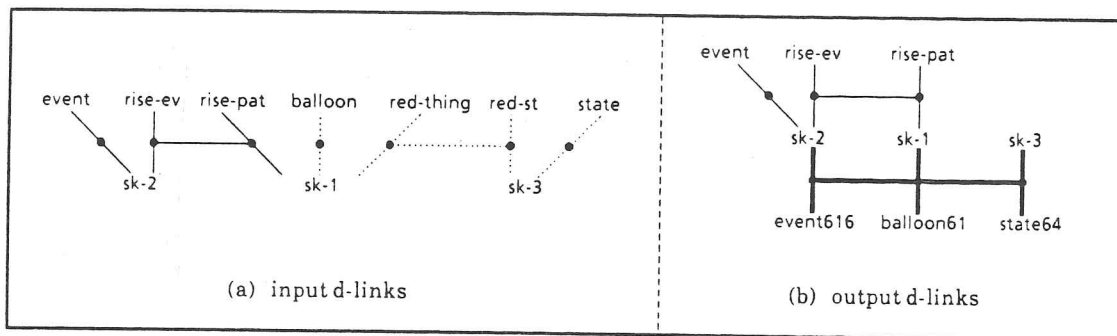


Figure 46: Reference resolution

Non-anaphoric descriptions

It is not always possible to find suitable referents among discourse entities, and in such cases 'unused' p-links are left in the network, where they are used in subsequent processing in the same way as other relational p-links, as described later.

An example of this sort of unused p-link occurs in the processing of

(23) *The price of gold is rising*

which is shown in figure 47.⁹

⁹ 'Proper' concepts in both i-links and p-links, i.e., concepts like John, gold, and eggs, are replaced to fit into this resolution scheme. This is as if instead of "gold" etc. appearing in the input, a skolem constant "gold0" were used along with a definite predication (GOLD "gold0"), a notation that would perhaps be more consistent.

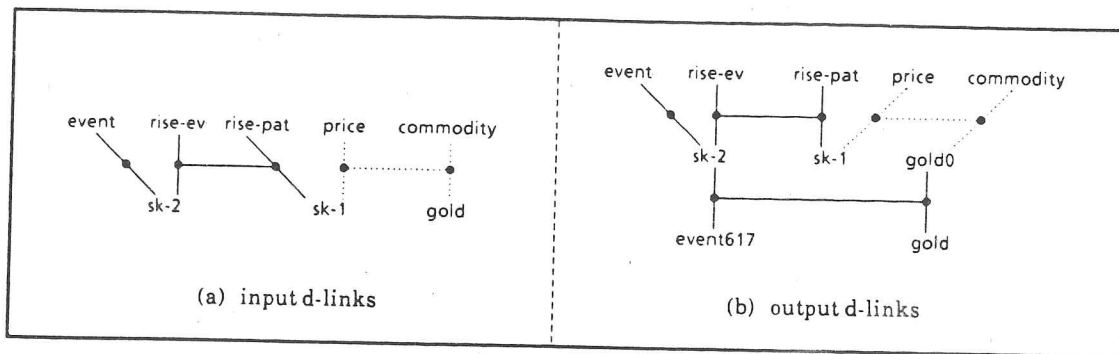


Figure 47: Partial reference resolution

Metaphorical descriptions

The process of matching descriptions is done by matching the p-links in the input against the existing network, and there is nothing to prevent metaphorical matches being found. Thus, for example, John could be identified as the referent of 'the monster' if he had previously been described as an ogre, and an event of criticism could successfully be referred to metaphorically as 'the attack'.

Summary

MINT's first phase of processing takes its input as naïve logical form and translates it into DREP notation by looking up translation rules for each predicate in its lexicon. The final form is a collection of d-links which have been stripped of dummy maps and have redundancy removed by amalgamation. Indefinite logical forms are translated to i-links and definite forms to p-links.

These d-links are used as input to the reference resolution phase of processing, which resolves the simpler definite references and renames indefinite entities with unique mnemonic names, so as to avoid name clashes with future inputs. These resolutions are encoded in a single 'sentence' i-link. More complex definite references are resolved as a by-product of the main descriptonal analogy processing, which is presented in the next few sections.

6.3 Redescription

We now turn to the main processing in MINT, where metaphorical interpretation is actually achieved. The next few sections describe the principal methods used in descriptonal analogy processing; how they are combined in the overall control structure is described in later sections. This first section presents the process of 'redescription'.

6.3.1 Redescription

In the rough outline of processing given in chapter 3, much was made of the idea of redescrbing target entities until a description was found which could either be taken at face value, as an 'abstraction', or was susceptible to recursive metaphorical interpretation. In MINT, this redescription operation is realized as the generation of new i-links by successive composition of chains of existing i-links.

Consider the fragment of network shown in figure 48. This fragment is a chain of length three up from the concepts event65 and balloon61. Successive composition of subchains yields the three composite i-links shown on the right,¹⁰ each of which corresponds to a description of its target entities, as indicated. In this way it is possible to build up a succession of such descriptions, typically in progressively more general terms.

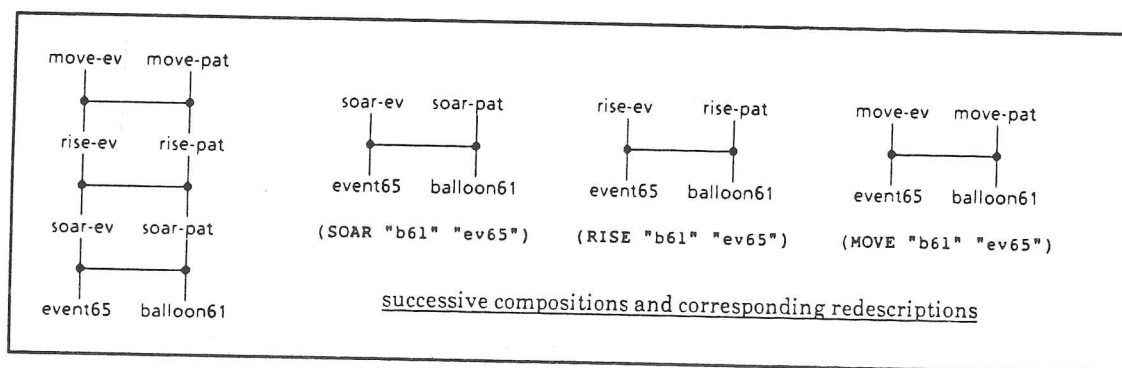


Figure 48: Redescription by successive composition

A more complex example involving a branching structure is shown in figure 49. In this case, the composite i-links have been omitted and the successive descriptions drawn in a tree structure to indicate their derivation.¹¹

6.3.2 Richer redescription

The process of redescription outlined above is rather restricted in that it will never introduce more target entities into its descriptions, since composite i-links can never have more targets than their parent chain. A much richer variety of redescrptions is allowed through the use of wide p-links to specify how definitive entities in a frame are related. These related entities can then be 'drawn into' the redescription process. As explained at the end of the last chapter, the use of p-links here can be seen as an extension of their use in specifying

¹⁰ The first of these is the trivial case of composing a chain of length one.

¹¹ In actual MINT processing, such a chain would start with the sentence i-link. This is omitted here for simplicity.

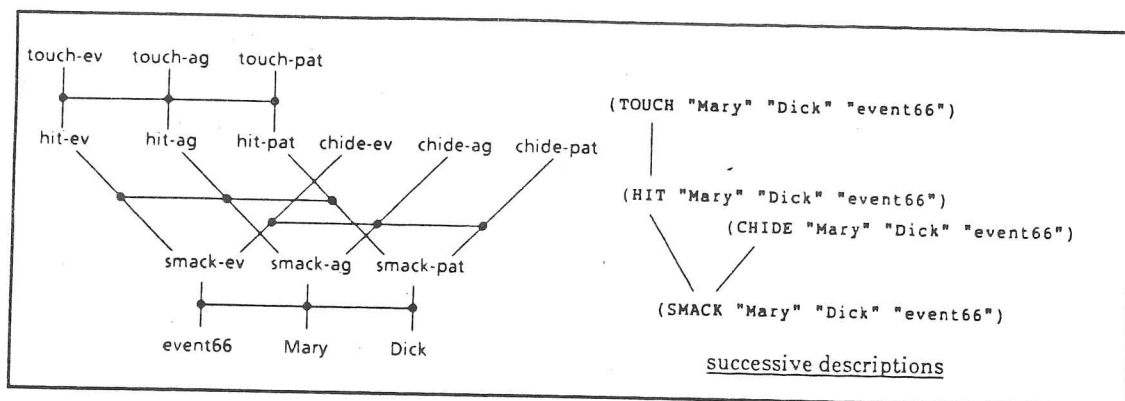


Figure 49: Branching redescription

argument restrictions, these relationships can be seen as *complex* argument restrictions specifying required relationships between (in the frame interpretation) the fillers of slots in the same frame.

Consider again the i-link corresponding to (RISE "balloon61" "event67"). Figure 50(a) shows this i-link in a chain whose top element is a p-link relating rise-pat-ht to rise-pat.

The presence of this p-link directs MINT to widen the i-link to include a concept corresponding to the height of balloon61 among its targets. The required concept is found by composing the chain to form a template and matching this template against the rest of the network, as shown in figure 50(a).

The match shows which concept corresponds to the height of balloon61, and this can be used to widen the original i-link, thereby increasing the number of target concepts available to redescription. This widening is shown in figure 50(b), together with an example of how the extra concept can be used in redescription.

This process can be seen to be one of reference resolution: an (albeit implicit) reference to the height of balloon61 has been resolved to height61. Indeed, this processing effects, as a by-product, the more complex definite reference resolution deferred from the earlier phase of processing, since these definite relationships were left in the network as p-links.

6.3.3 Concept evocation

The network created during processing is inevitably incomplete. There is to all intents and purposes no limit to the number of concepts and links relating them to other concepts that ought to be present. For example, whenever a concept corresponding to some physical object is present, there really ought to be more concepts corresponding to its size, its colour, its weight, its density, and so on. Having so many concepts and links around is clearly

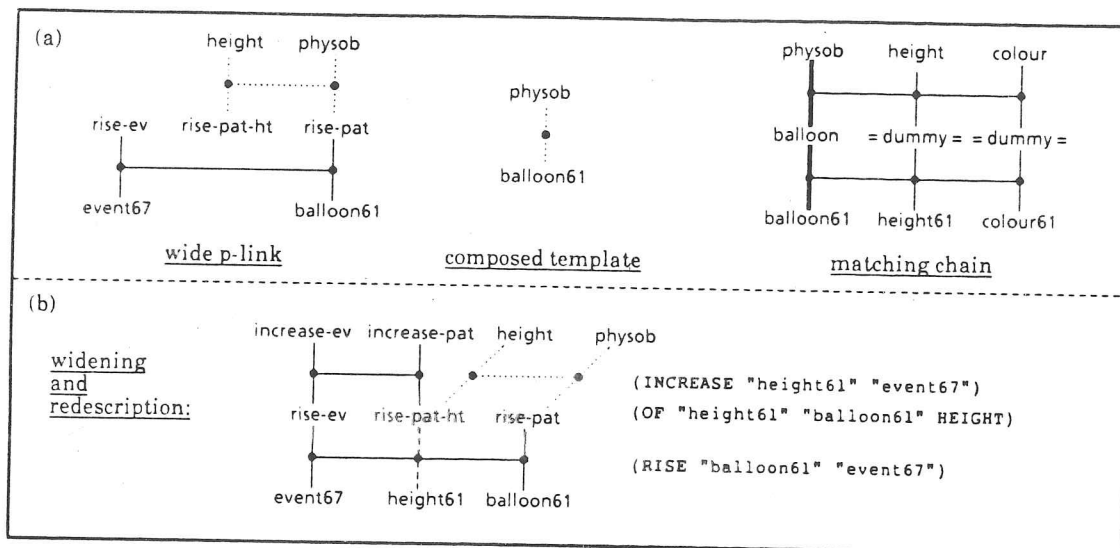


Figure 50: Richer redescription by matching and widening

impractical, so the solution adopted is to leave the existence of such concepts implicit, only creating them by 'concept evocation' *as and when necessary*, that is to say, as directed by p-links.

Suppose, for example, the matching process described just now found the matching chain shown in figure 51(a). This matching chain fails to provide an existing concept for the height of balloon61. To rectify this absence, a new concept with an appropriate name, height61, is created, and the matching chain widened to accommodate it, as shown in figure 51 (b). Processing can then continue just as before, with the newly evoked concept being included in the redescription process.

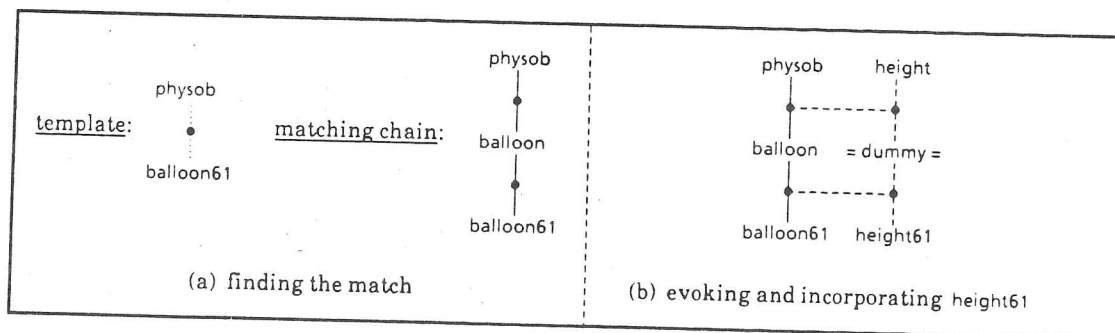


Figure 51: An alternative match requiring concept evocation

6.3.4 Summary of redescription

We now have a mechanism for obtaining successive redescriptions of target entities, which can involve the inclusion of other related entities, evoking them if they do not already exist in the network. The overall approach is to search through the network, working up (possibly

branching) chains of i-links and using wide p-links to direct the inclusion of the extra entities.

6.4 Metaphor interpretation

We now have the machinery to do some real metaphor interpretation. The three mechanisms of chapters 3 and 4, viz abstraction, metaphorical reference resolution, and generalized metaphorical reference resolution are all represented in MINT.

6.4.1 Abstraction

The simplest of the interpretation methods is abstraction, where successive descriptions are generated until one or more is found that is well-formed. These well-formed descriptions can then be accepted as literal. In MINT, all such well-formed descriptions (with respect to the current interpretation)¹² are marked as such and passed through to the interpretation acceptance component *en bloc*, where those that are considered semantically unacceptable, or pragmatically unlikely, are filtered out.

An illustration of this interpretation process at work on the example

(24) **The car drinks petrol*¹³

is shown in figure 52, where, for clarity, argument restrictions represented by p-links are only shown for the -ag concepts.

The bottom i-link represents the original description of the car, (DRINK "car61" "petrol" "event69"), which is judged metaphorical, as there is no matching chain linking car61 to animal. For just the same reason, the next description of the car, (INGEST "car61" "petrol" "event69"), is also judged metaphorical. The third description, (USE "car61" "petrol" "event69"), however, is judged literal, since there *is* a matching literal chain.¹⁴ This literal description is passed on by MINT to the interpretation acceptance component.

This processing can be related to the theoretical ideas of chapters 3 and 4 in two ways. In the informal notation, which gives a better idea of *dynamic* processing, the sequence of events above would be written

¹² Interpretations will be discussed in due course.

¹³ This example is represented as an event, whereas the utterance should really be given a habitual reading. The representation of event semantics implemented in MINT is not capable of making this distinction.

¹⁴ 'System' is a description intended to cover both animals and machines.

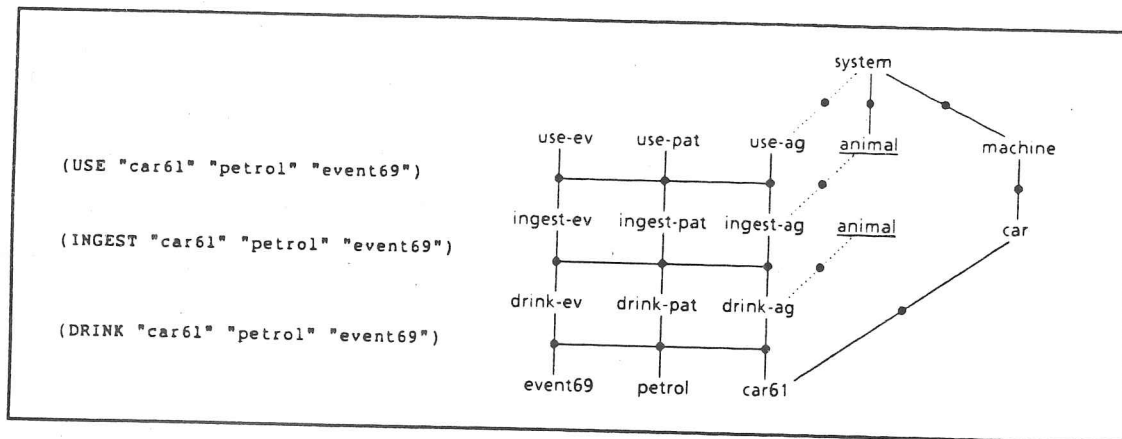


Figure 52: "The car drinks petrol"

- *The car drinks petrol
- *The car ingests petrol
- The car uses petrol.

In the analogical notation of chapter 3, which is better suited for a *static* view of description inheritance, the final, well-formed description is derived as follows

$\uparrow\uparrow$ $\langle \text{event68} \rangle, \langle \text{the car} \rangle, \langle \text{petrol} \rangle$
 $\uparrow\uparrow$ $\langle \text{drink-ev} \rangle, \langle \text{drink-ag} \rangle, \langle \text{drink-pat} \rangle$
 $\uparrow\uparrow$ $\langle \text{ingest-ev} \rangle, \langle \text{ingest-ag} \rangle, \langle \text{ingest-pat} \rangle$
 \Rightarrow $\langle \text{use-ev} \rangle, \langle \text{use-ag} \rangle, \langle \text{use-pat} \rangle$
 \Downarrow $\langle \text{use-ev} \rangle$ is the using by $\langle \text{use-ag} \rangle$ of $\langle \text{use-pat} \rangle$
 \Downarrow $\dagger \langle \text{ingest-ev} \rangle$ is the using by $\langle \text{ingest-ag} \rangle$ of $\langle \text{ingest-pat} \rangle$
 \Downarrow $\dagger \langle \text{drink-ev} \rangle$ is the using by $\langle \text{drink-ag} \rangle$ of $\langle \text{drink-pat} \rangle$
 \Downarrow $\dagger \langle \text{event68} \rangle$ is the using by $\langle \text{the car} \rangle$ of $\langle \text{petrol} \rangle$.

This abstraction process allows literal input to pass through MINT unscathed, since such an input will be translated into literal i-links, which will be accepted and passed on without any redescription taking place.

6.4.2 Metaphorical reference resolution

The abstraction process just described tends to deliver rather vague interpretations of input metaphors, which is useful as a 'fall-back' when more specific interpretation is not possible. More specific interpretation is possible when the richer redescription process encounters d-links representing core analogies in its matching chains, a pattern of processing which is equivalent to the metaphorical reference resolution of chapter 4.

As an example, consider the MORE IS UP systematic metaphor, where increasing and decreasing quantities are spoken of as if they were rising and falling objects. The analogy underlying this systematic metaphor is shown in its i-link form in figure 53. This analogy may at first seem a little unusual in that quantity is seen as playing the rôle of both physical object and its height, but the sharing of targets is quite legal in d-links (c.f. "John kicked

himself") and this does seem accurately to reflect the use of MORE IS UP in describing quantifiable entities.¹⁵ The underlying analogy for MORE IS UP is expressed by the (metaphorical) i-link in figure 53. It might be summed up as follows: 'a quantity (such as a temperature) can be spoken of as a physical object (which goes up and down) as long as its height is interpreted as the quantity itself'.

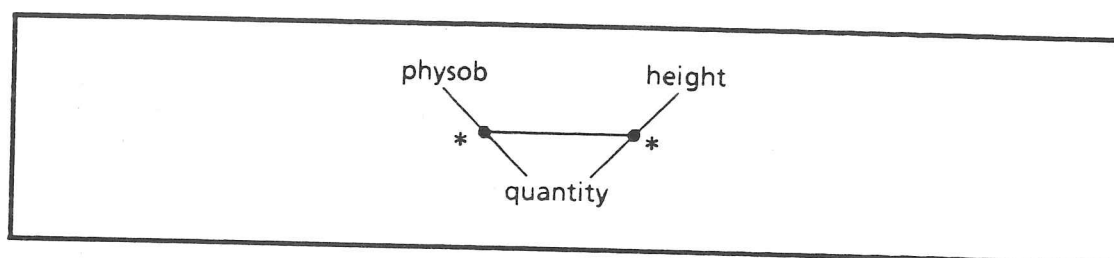


Figure 53: MORE IS UP

Just how this metaphorical i-link is used in processing the example

(25) *The temperature is soaring*

is illustrated in figure 54. It can be seen that processing proceeds very much as it did in the earlier literal examples of soaring, the only difference being that the chain found to match the p-link relating rise-pat to rise-pat-ht is this time metaphorical rather than literal.

The processing in this example¹⁶ can be written in the informal notation of chapter 3 as

- *The temperature is soaring
- *The temperature is rising
- *The height of the temperature is increasing
- *→ The temperature is increasing.

In the more formal notation, the matching chain is used to derive a metaphorical description of <temperature61> as follows:

- ↑↑ <temperature61>
- ↑↑ <temperature>
- ↑↑ <quantity>
- ↑↑ <physob>
- ⇒ <height> is <physob>'s height
- ↓↑↑ <quantity> is <quantity>'s height
- ↓↑↑ <temperature> is <temperature>'s height
- ↓↑↑ <temperature61> is <temperature61>'s height

and this metaphorical description is then used in metaphorical reference resolution:

¹⁵ This double rôle of quantity could be put down to a metonymic effect, whereby a quantity is used metonymically to refer to its value. There will be more discussion of metonymy in chapter 7.

¹⁶ This is a rather simplified account of this example – MINT actually represents, in addition, that soaring is rapid rising to a great height.

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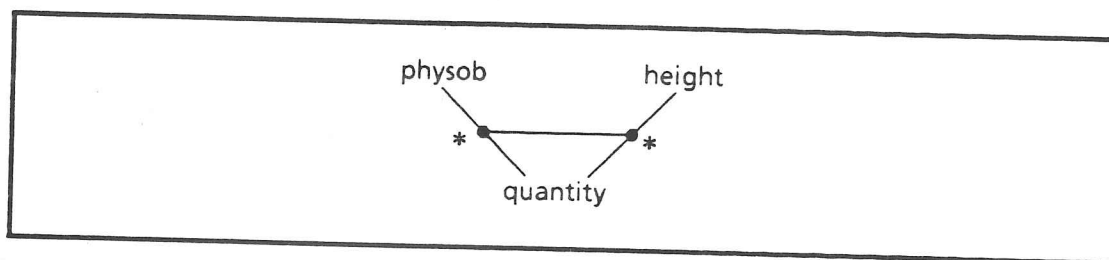


Figure 53: MORE IS UP

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 ↑↑ <temperature>
 ↑↑ <quantity>
 ↑↑ <physob>
 ⇒ <height> is <physob>'s height
 ↓↑ ††<quantity> is <quantity>'s height
 ↓↑ ††<temperature> is <temperature>'s height
 ↓↑ ††<temperature61> is <temperature61>'s height

and this metaphorical description is then used in metaphorical reference resolution:

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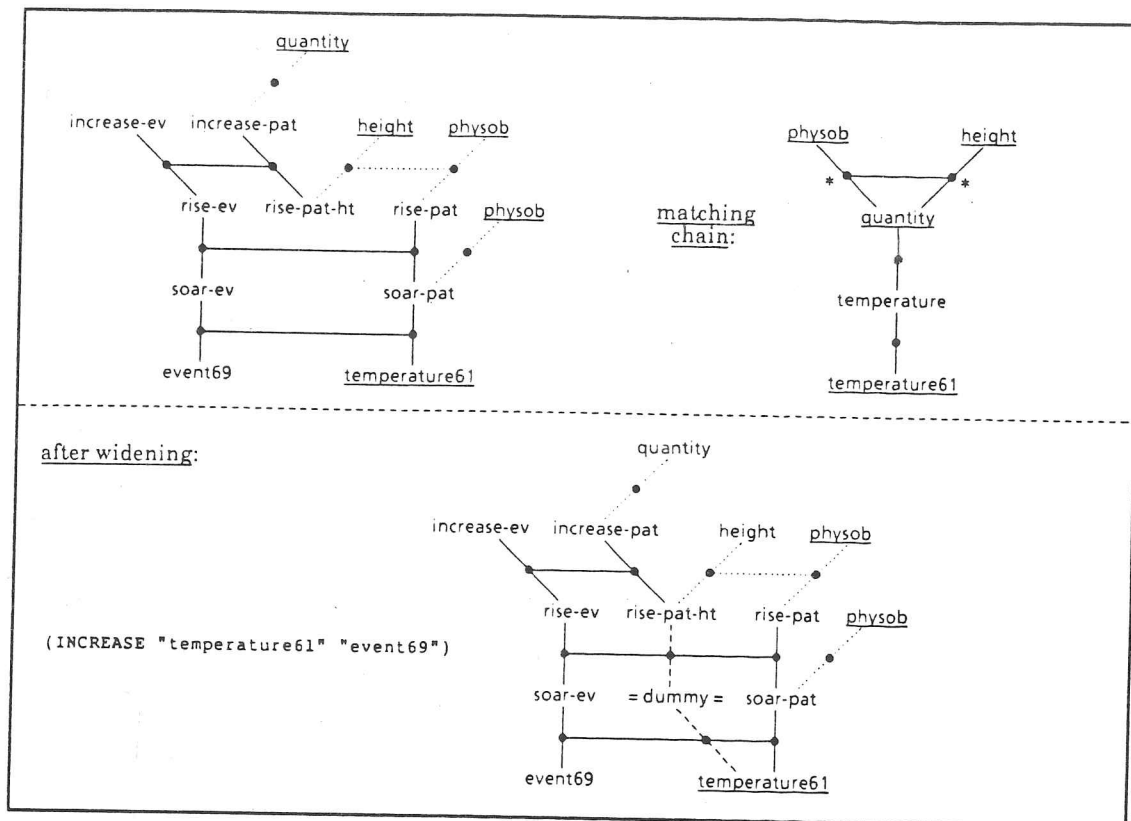


Figure 54: "The temperature is soaring"

- ↑↑ <event69>, <temperature61>
- ↑↑ <soar-ev>, <soar-pat>
- ⇒ <rise-ev>, <rise-pat>
- ⇒ <rise-ev> is the increasing of <rise-pat>'s height
- ⇒ †<soar-ev> is the increasing of <soar-pat>'s height
- ⇒ ††<event69> is the increasing of <temperature61>'s height
- <†> ††<event69> is the increasing of <temperature61>

The same metaphorical description of <temperature61> can be used to interpret other examples of MORE IS UP, such as

(26) *The temperature is low,*

which is illustrated in figure 55. Unfortunately, it is very hard to come up with literal terms to describe quantities, so it is presumed here that the application would require 'high' and 'low' to describe physical objects, whereas 'great' and 'little', in their core senses, would be presumed to describe quantities.¹⁷ The processing runs as follows:

- *The temperature is low
- *The height of the temperature is little
- *→ The temperature is little.

¹⁷ It would of course be possible to use coined predicates such as 'Qgreat' and 'Qlittle' to avoid the clash with English words.

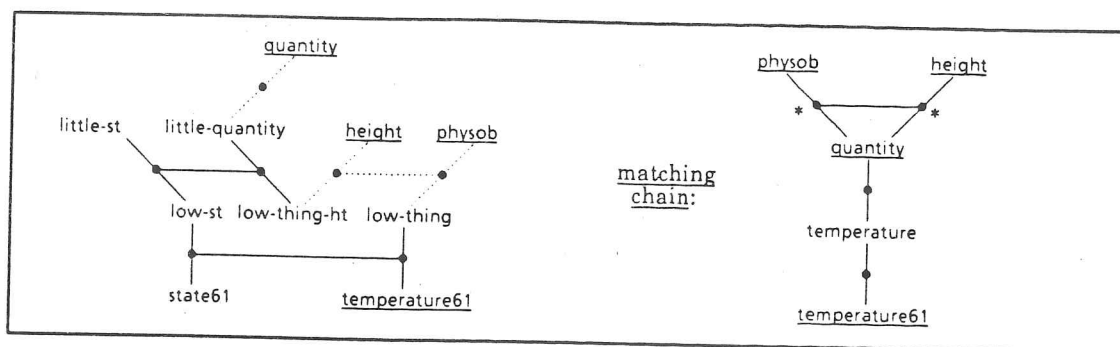


Figure 55: "The temperature is low"

6.4.3 Generalized metaphorical reference resolution

It was seen in chapter 4 that a more general idea of metaphorical reference resolution was required to deal with instances of systematic metaphor that did not rely on the metaphorical interpretation of functional attributes of entities, such as *the* height of a quantity, or *the* temperature of a person. This extended metaphorical interpretation is achieved in MINT through the use of 'associated d-links'. Here, descriptions of *predications* are reinterpreted, rather than descriptions of simple attributes.

Consider the example of UNDERSTANDING IS SEEING

(27) *John saw the idea.*

It is not clear that there is any particular property of <the idea> which is being alluded to here, and which would enable the sort of processing described above to be applied usefully. Instead, it is necessary to interpret 'see' as 'understand', and this can be done by noticing and exploiting the association of the systematic metaphors UNDERSTANDING IS SEEING and IDEAS ARE OBJECTS.

Figure 56 (a) shows the fragment of network relevant to this example; the double horizontal line indicates the association of two i-links. The processing of this example proceeds as before, i.e., the p-link up from see-pat prompts a search for a matching chain (one with idea61 as a target and physob as a source) and a suitable (metaphorical) chain is found, as shown.

Here, though, there is a difference. The top i-link of the matching chain is seen to have an associated i-link, and an attempt is made to interpret the original description as a manifestation of the systematic metaphor encoded by this associated i-link, i.e., by replacing occurrences of *see-ev etc.* with *understand-ev etc.* In this case it is possible to 'interpret' the original chain in this way, and the resulting i-link (dashed) is shown in figure 56 (b).¹⁸ This new description is seen to be well-formed, so is passed on to the acceptance

¹⁸ Actually, a new i-link is created, rather than the sources of the old chain being replaced.

component. This process of interpretation guided by an associated i-link is called 'construal'.

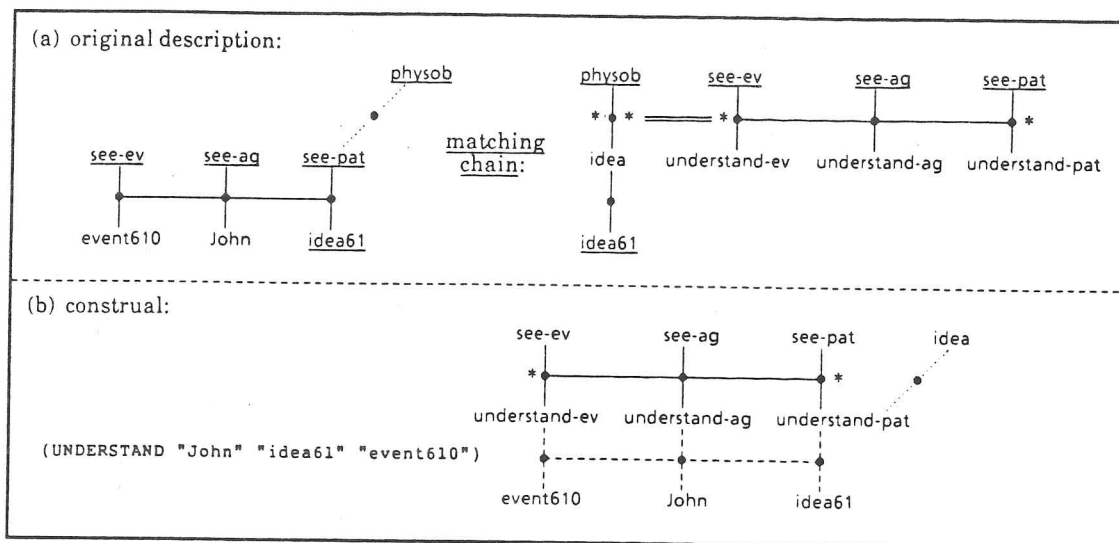


Figure 56: "John saw the idea"

Informally, the construal runs as follows:

*John saw the idea
 *→ John understood the idea.

A slightly more complex example of construal occurs in the processing of an instance of ARGUMENT IS WAR:

(28) John shot down Bill's theory

The processing of this¹⁹ is shown in figure 57, and runs as follows:

*John shot down Bill's theory
 → *John attacked Bill's theory
 *→ John criticized Bill's theory.

Notice that, as with widening in redescription and concept evocation, construal is controlled by the presence of p-links representing argument restrictions – it is not the case that *any* chain with *see-ev etc.* as sources will be construed to be an i-link with *understand-ev etc.* for sources – this construal will only happen when the patient of the seeing is some sort of *idea*.

Notice also that there is nothing different about the d-link representing UNDERSTANDING IS SEEING apart from its association with that representing IDEAS ARE OBJECTS – the first represents the fact that an understanding can be described (metaphorically) as a seeing, and

¹⁹ Note that this is a much simplified account of MINT's treatment of this example – Another branch of redescription has it that shooting down is destroying, and the destruction of an argument is interpreted (by metaphorical reference resolution) as the reduction of its 'convincingness' to nothing.

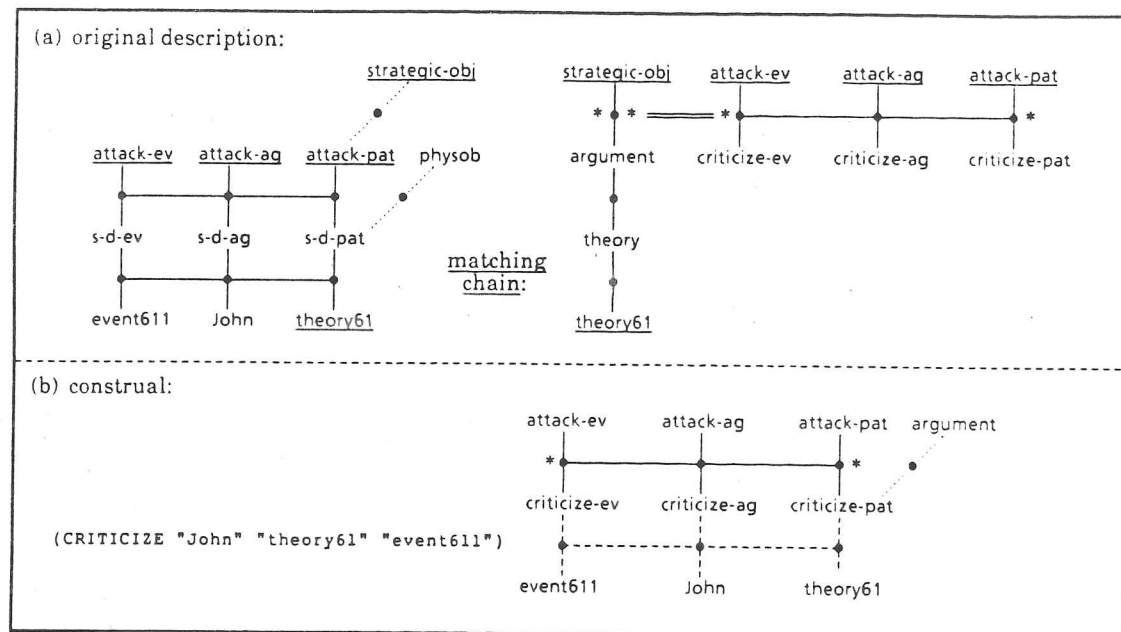


Figure 57: "John shot down the theory"

the second that an idea can be described (metaphorically) as an object.

Literal associations

Up until generalized metaphorical reference resolution, the MINT interpretation described took no account of whether i-links were labelled as literal or metaphorical, except in making the final judgement as to the well-formedness of a description. In construal, however, it might appear that special treatment is being given to metaphorical i-links in that they can be associated with other metaphorical i-links. This, however, is a misleading impression – it would be quite possible, and indeed useful, to associate literal i-links, a tactic which would enable the interpretation of general predicates to more specific predicates. An example parallel to the UNDERSTANDING IS SEEING example is shown in figure 58, where the general predicate 'steer' is construed to be the more specific 'pilot' in the case of an aeroplane. It is easy to see how similar interpretations could be generated for other modes of transport.

There will be further discussion of the rôle of associated d-links in chapter 7.

6.5 Matching i-links and consolidation

The matching operations described above have all matched templates generated from p-links – either as part of the well-formedness checking process, or as a way of identifying more targets to include during redescription. MINT processing, however, also matches i-links, or rather chains of i-links, directly. This is the basis of the final technique described used in

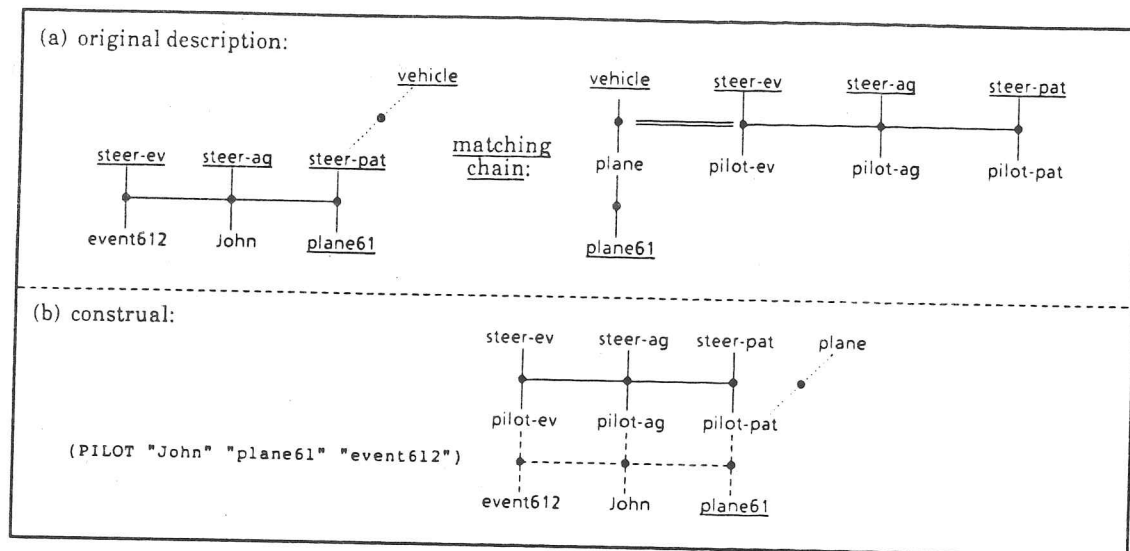


Figure 58: "John steered the aeroplane"

MINT's main processing – 'consolidation'.

The prime motivation behind this matching is to detect and reduce duplication of descriptions in the network, and at the same time to consolidate distributed information, by combining matching chains. There are, however, other beneficial effects, such as the interpretation of certain metaphors and the attachment of prepositional arguments.

Consider the situation depicted in figure 59(a). Here a description of the relationship between John and colour62 is found to match (partially) an existing chain. The two chains are 'consolidated' by widening (figure 59(b)), and one of them is made 'invisible' to the matching algorithm to prevent unnecessary extra matches being found in subsequent matching operations.²⁰

6.5.1 Metaphor interpretation by consolidation

Occasionally, consolidation can effect metaphor interpretation. Figure 60 shows how this works in the case of "The summer rolled by", an instance of the systematic metaphor TIME IS A MOVING OBJECT. The bottom i-link in each chain arises from initial processing of the input utterance, the upper i-links or the chains are part of the 'background' knowledge encoded in the network.

That this example can be interpreted by consolidation is a result of the fact that a time interval has a unique elapsing event associated with it (time intervals only elapse once!).

²⁰ The reason for widening *both* chains is that both widening operations can cause subchains to be put on the processing agenda, as described later.

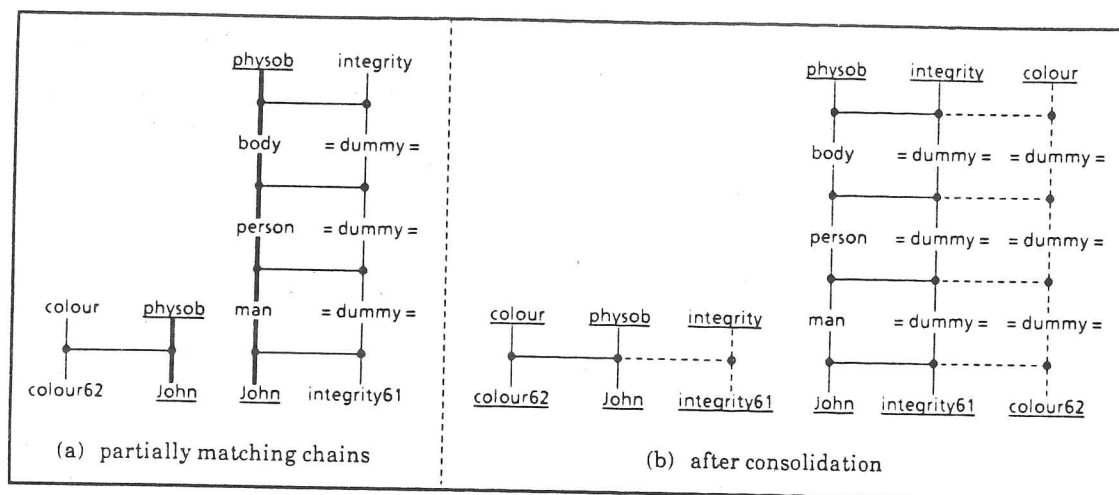


Figure 59: Consolidation

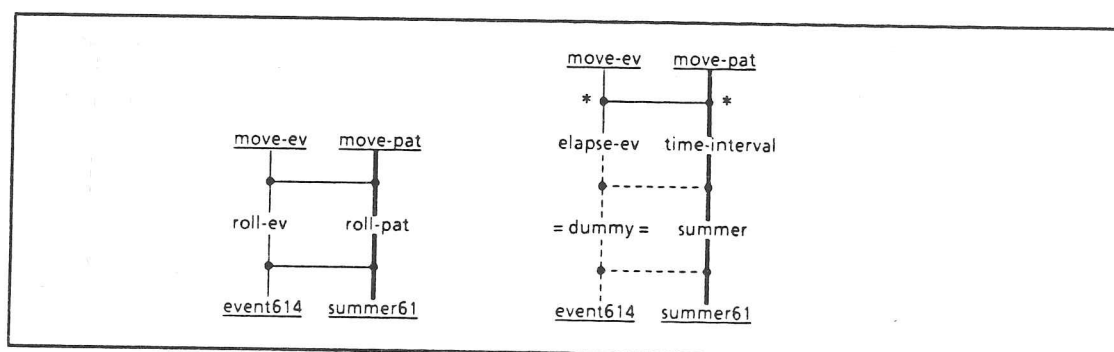


Figure 60: "The summer rolled by"

6.5.2 Attachment of prepositional arguments by consolidation

The consolidation mechanism enables the proper attachment of prepositional arguments to input predications in the scheme employed by MINT.²¹

For example, the input

(29) *Mary struck John with a rolling-pin*

which has the indefinite logical form

(STRIKE "Mary" "John" "sk-21") (EVENT "sk-21")
(WITH "sk-22" "sk-21") (ROLLING-PIN "sk-22")

results in four i-links, two of which have the event concept event615 as a target (as shown in figure 61).²² When processing these input i-links, MINT finds that the one matches a

²¹ There is no theoretical commitment to this representation of prepositions implied – this is just a simple, but effective way to allow prepositions to be used in input examples.

²² The concept renaming is done during reference resolution.

chain involving the other, and when these two chains are then consolidated, rolling-pin61 gets incorporated as a target of the right hand i-link as a result of widening.

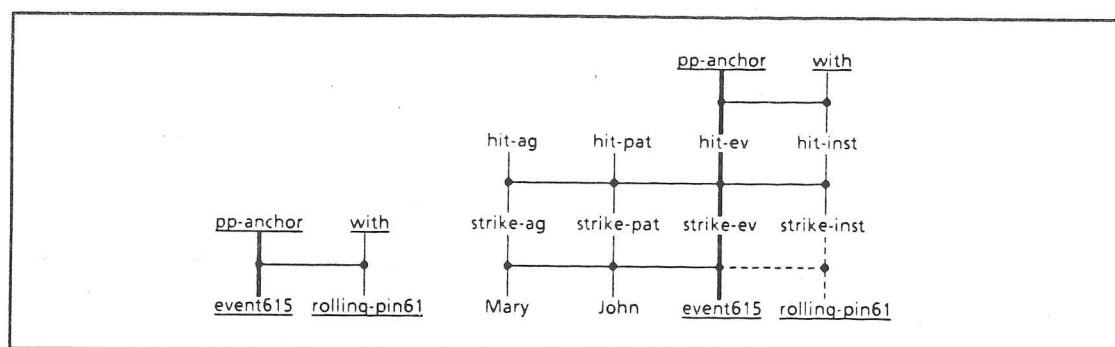


Figure 61: Prepositional attachment by consolidation

An interesting feature of this example is that strike-inst inherits its description as the 'with' rôle of strike-ev from hit-inst. In general, this inheritance of prepositional rôles allows a significant saving in i-links in the network.

6.6 Multiple perspectives and interpretations

The various forms of processing described above have depended to a large extent on finding matches in the network and using these matches to achieve interpretation. In the simple cases considered, there has only ever been one match for each query, but in general, more than one match can be found. These differing matches can be seen to correspond to different perspectives on their target concepts, and choosing between matches is MINT's method of choosing between interpretations.

Consider the processing of

(30) *Bill was shattered.*

This has at least two interpretations. The first of these is literal – Bill was physically shattered – and the second is metaphorical – Bill was psychologically shattered. The fragment of network relevant to MINT's processing of this example is depicted in figure 62.

In this figure, it can be seen that there are two matching chains (emphasized) with Bill as target and structure as source; the two chains diverge when they reach person, one continuing through body (the physical object), and the second through ego (roughly, the thinking mind). These two alternatives correspond to different *perspectives* on Bill – the physical and the psychological, and it is easy to see how the choice of perspective dictates the interpretation: in the physical case, a concept is evoked for the physical integrity of

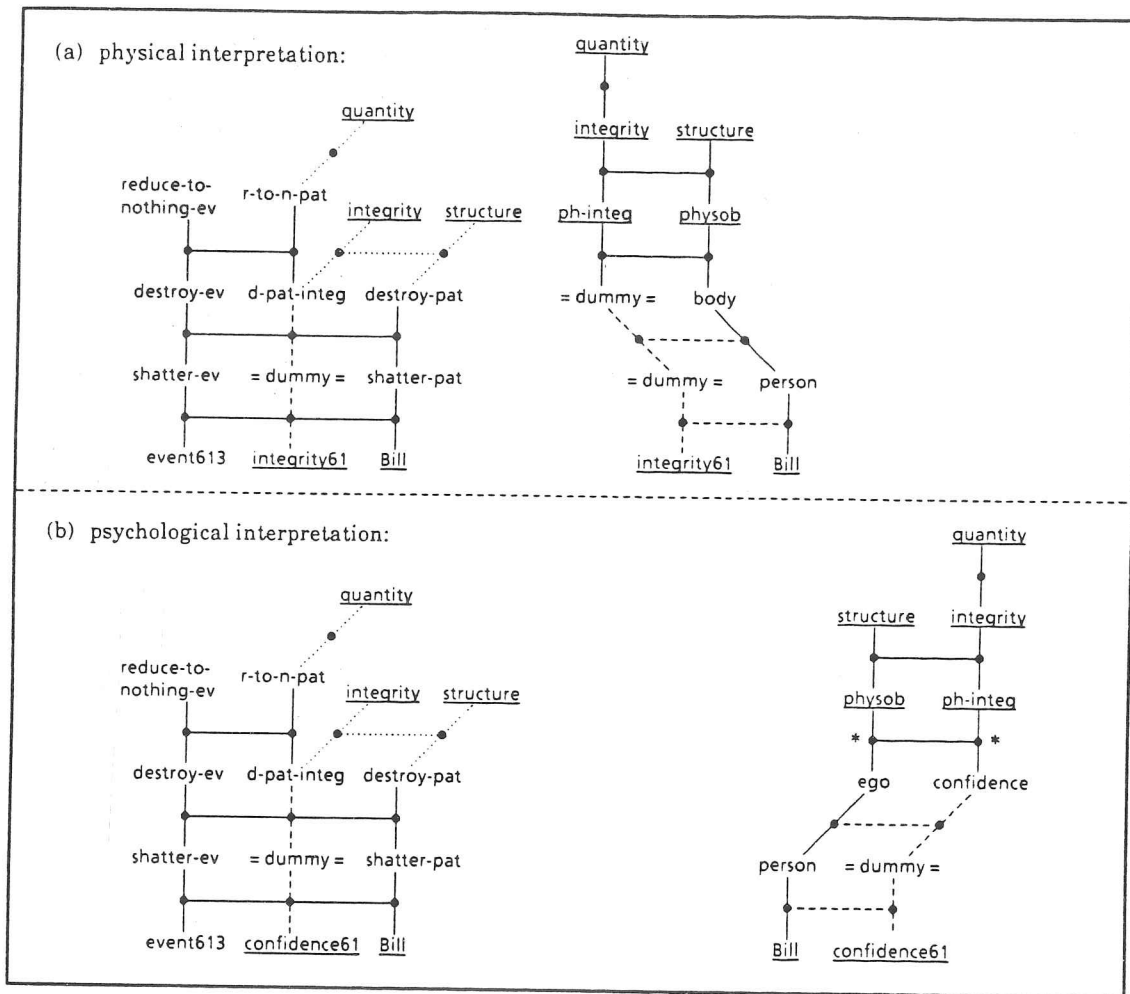


Figure 63: Two interpretations of "Bill was shattered"

The suppression of alternative perspectives has the effect of making the process of well-formedness checking a rather stronger process, i.e., one of checking for well-formedness *with respect to the current interpretation*. For example, in the psychological interpretation of the "Bill was shattered" example, the description "Bill was destroyed" would be judged ill-formed, since a literal matching chain from Bill to structure would not be found (the original literal chain having been suppressed). This strengthened idea of well-formedness with respect to the current interpretation has moved closer to the idea of 'literalness' in that it rejects otherwise well-formed predications which are inconsistent with the current interpretation. This strengthened well-formedness test is what enables MINT to pass on only good candidates for literal paraphrases of its input.

6.7 Overall control of descriptive analogy processing

The processes described above are the essential mechanisms by which metaphor interpretation is achieved in MINT, the control issues, however, have so far only been

touched on, and it is the purpose of this short section to describe these issues. The next, and final section of this chapter gives an example showing this control mechanism at work.

The two main problems of control are the ordering of redescription, due to branching structures in the network, and the branching of interpretations, due to multiple matching chains found during the matching of i-links and p-links.

6.7.1 Control of redescription

The control of redescription is handled by means of an agenda. Each agenda item is a chain of i-links. As seen earlier, each of these chains corresponds to a description of its targets.

The agenda is initially set to the chain of length one comprised solely of the sentence i-link resulting from reference resolution, but more chains are added as agenda items are processed (a) as successive redescription proceeds up chains, (b) as a result of widening operations, and (c) as a result of construal using associated d-links. When a new chain is added to the agenda, it is inserted in a position such that the shortest chains are processed first. This ensures an essentially breadth first ordering to redescription.

6.7.2 Control of interpretations

If a matching operation results in more than one matching chain, each chain is taken to correspond to a different perspective on its targets, and hence a different interpretation. At such a point, a record is kept of the current state of processing, and the heuristically determined 'best' match is pursued, while the other matching chains are suppressed, as explained above. Further branching of interpretations may occur as a result of subsequent processing. If, ultimately, this interpretation is rejected, processing backtracks to last of these branch points, and the next best branch is selected, and so on. In this manner, interpretations are processed depth first.

6.7.3 Agenda item processing algorithm

Items on the agenda (chains of i-links) are processed one by one. Each item is processed as follows:

Phase 1:

- attempt to match this chain of i-links against rest of network
- if there is a match*, consolidate
- if not,
 - for each p-link up from the sources of this chain
 - attempt to match the composition of the chain and this p-link
 - if there is a match*, widen chain to include more targets**,
 - evoking concepts if necessary***

Phase 2:

- assign well-formedness to this chain
- if well-formed, accept this description (and go on to next item on agenda)
- if ill-formed
 - if there are associated i-links, attempt construal
 - if successful, put construal on agenda and go on to next item
 - put extensions up literal i-links of this chain on agenda

*If there is more than one match, choose the 'best' and suppress the others, backtracking to this point if interpretation rejected.

**This widening operation may result in the addition of subchains to the agenda, in which case processing of the current chain is abandoned.²⁵

***Concept evocation may result in more chains being added to the agenda.

As can be seen, interpretation of an agenda item proceeds in two phases, the first effectively chooses the current interpretation, since it is in the first phase that all the relevant matching is done. The second phase assigns well-formedness with respect to this interpretation; if the judgement is that the current description is well-formed, then it is accepted (passed on to the interpretation acceptance component), otherwise, the current chain is interpreted further, either by construal, as described above, or, failing that, by simple redescription. Processing stops when the agenda is finally exhausted, which happens when all the branches of redescription can no longer be extended, or they reach a well-formed description, or they are interpreted by construal. To ensure termination, there is also a check to trap cycles and a limit on the length of chain considered (currently 8).

Widening operations on a chain generally augment the information represented by subchains (figure 64). To take account of this new information, these subchains are added to the agenda, as indicated. This results in a sort of backtracking of redescription, as these subchains may well have been processed before.

These control processes can be seen at work in the simple example in the next section.

6.7.4 A short example

This section describes in some detail the overall processing involved in interpreting the manifestation of ARGUMENT IS WAR

²⁵ The augmented version of the current chain will be processed in due course.

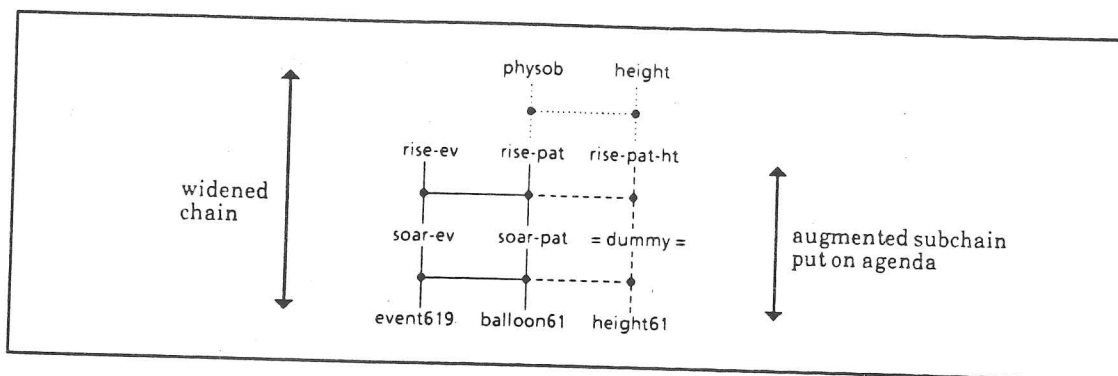


Figure 64: Widening leads to new agenda items

(31) *John assailed Bill's theory.*

This simple example shows much of the operation of the control mechanism, without involving too many steps. The input naïve logical form equivalent is

indefinite:

(ASSAIL "John" "sk-1" "sk-2") (EVENT "sk-2")

definite:

(OF "sk-1" "Bill" THEORY) (THEORY "sk-1")

and the d-link version of this after reference resolution is shown in figure 65.

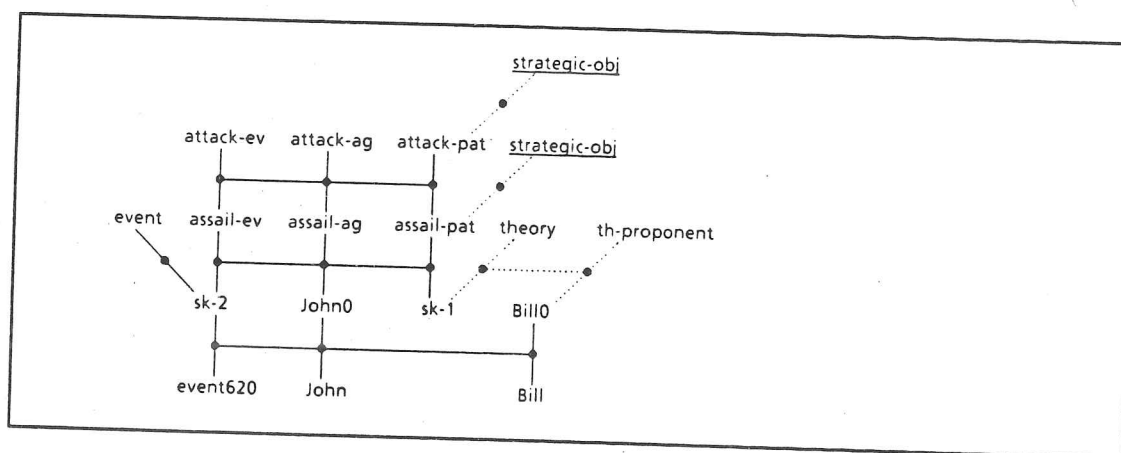


Figure 65: Network for "John assailed Bill's theory"

Processing then proceeds as follows: (emphasis in the figures shows the chain being processed and matching chains)

Figure 66(a) shows the first agenda item, the sentence i-link, being processed. No match for this chain is found in the rest of the network, so p-links up from its targets are checked. Here, a match is found,²⁶ the concept theory61 evoked, and the two chains widened accordingly (figure 66(b)). The result of this widening is to put the newly augmented

²⁶ Actually, the match is created specially because this p-link corresponds to a definite predication. This is necessary to cope with definite reference being used to introduce previously unsuspected entities.

sentence i-link on the agenda.

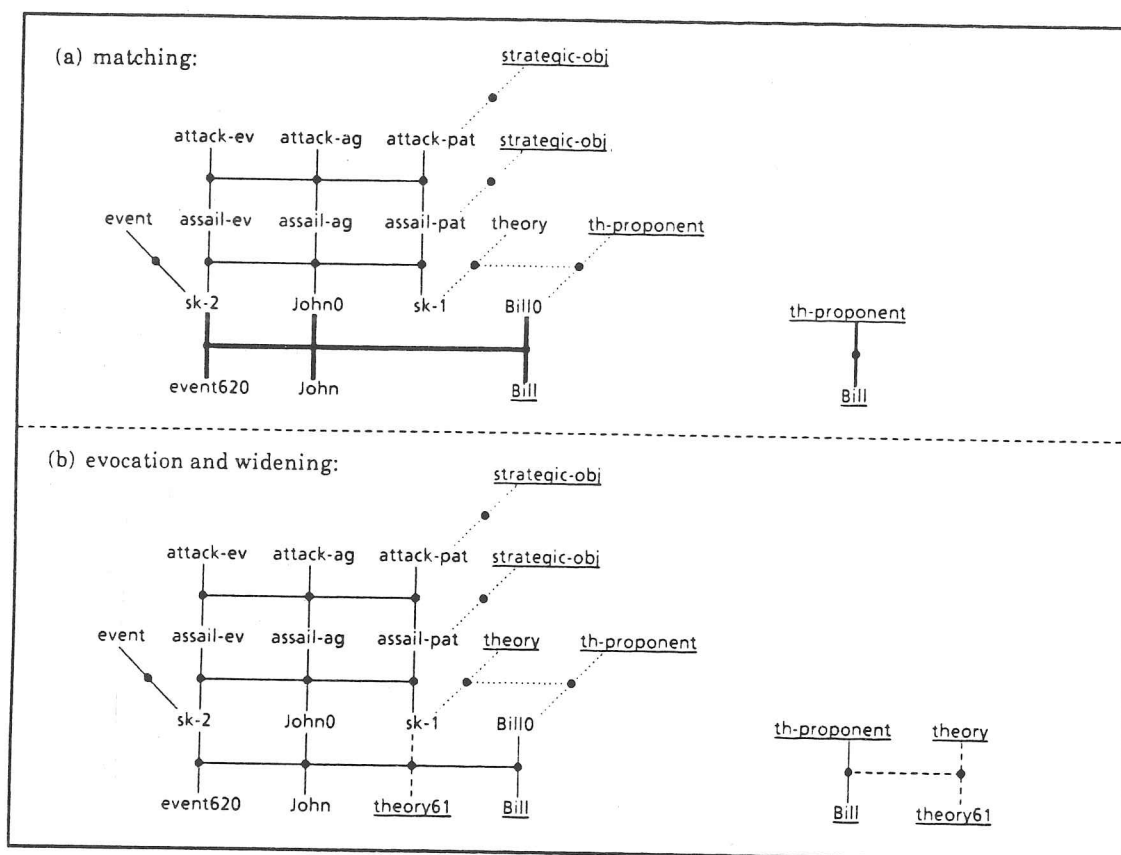


Figure 66: Processing of the sentence i-link

Figure 67 shows the augmented sentence i-link being processed. Again, there is no direct match, and so the p-links are checked for matches. The same match as before is found, but no new widening is necessary. Phase 2 is then invoked: the chain is not judged well-formed,²⁷ so the two extensions of the current chain (corresponding to the two i-links up from the sentence i-link) are put onto the agenda.

Figure 68 shows the processing of the first of these chains, which corresponds to the description (EVENT "event620"). This has no direct match, and since there are no p-links, it is judged by default to be well-formed, and the corresponding description, (EVENT "event620"), is passed on as part of the interpretation. Because of this well-formedness, no further chains are put onto the agenda from this branch of redescription.

The next chain to be processed corresponds to the description (ASSAIL "John" "theory61" "event620"), as shown in figure 69. There is no match for the chain itself, but there is a metaphorical match for the p-link up from assail-pat, though no

²⁷ The sentence i-link is *never* considered well-formed, this effectively forces processing of the other input i-links.

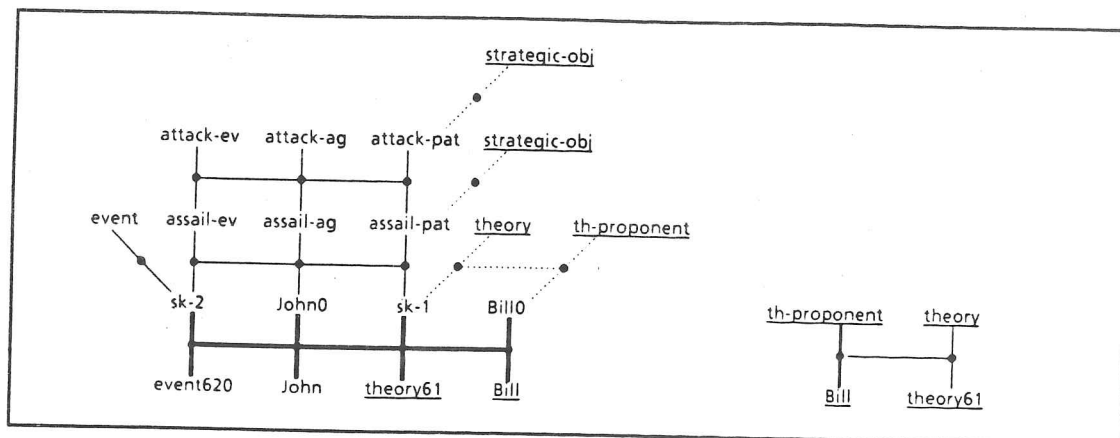


Figure 67: Processing of the augmented sentence i-link

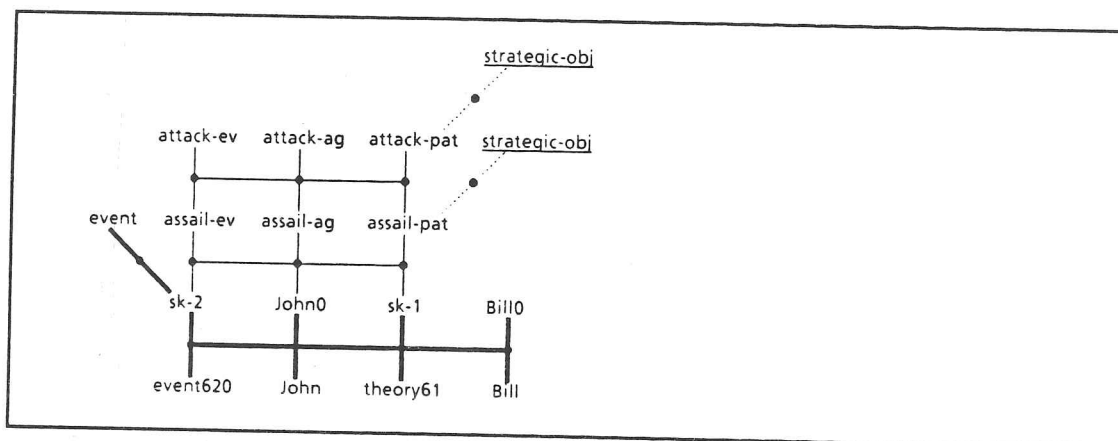


Figure 68: (EVENT "event620")

widening is needed. Phase 2 finds the description ill-formed (because of the metaphorical match), but construal is not possible. The longer chain formed by adding in the next i-link is therefore put onto the agenda.

Next, the chain shown in figure 70, corresponding to (ATTACK "John" "theory61" "event620"), is processed. Again, there is no direct match. The same match as before is found for the p-link, but again no widening is called for. In phase 2, the description is found to be ill-formed, but this time construal is possible, as shown. The resulting interpreted i-link ((CRITICIZE "John" "theory61" "event620")) is put on the agenda.

Finally, when this construed i-link is processed (figure 71), a literal matching chain is found for the p-link up from criticize-pat and so the description is judged well-formed and passed on. This completes the MINT processing.

A summary of the processing of this example, as produced by the system, is as follows:

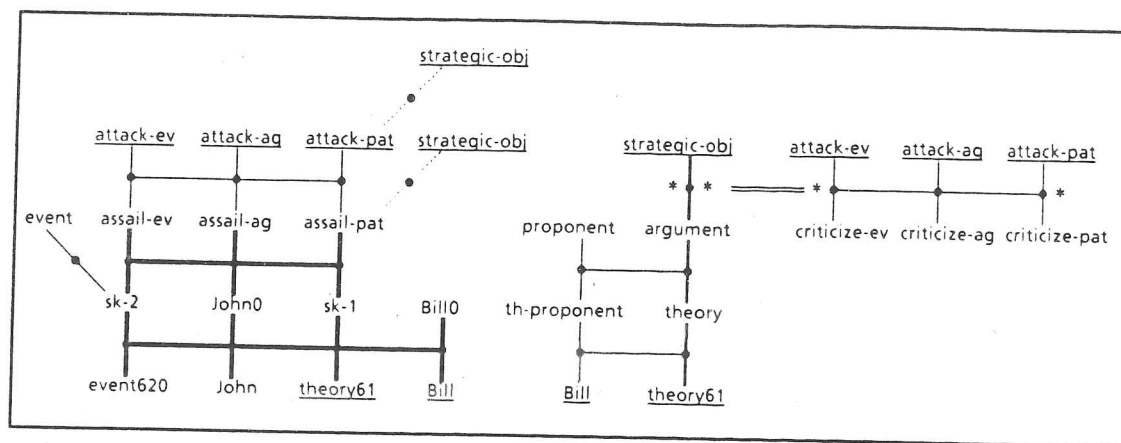


Figure 69: (ASSAIL "John" "theory61" "event620")

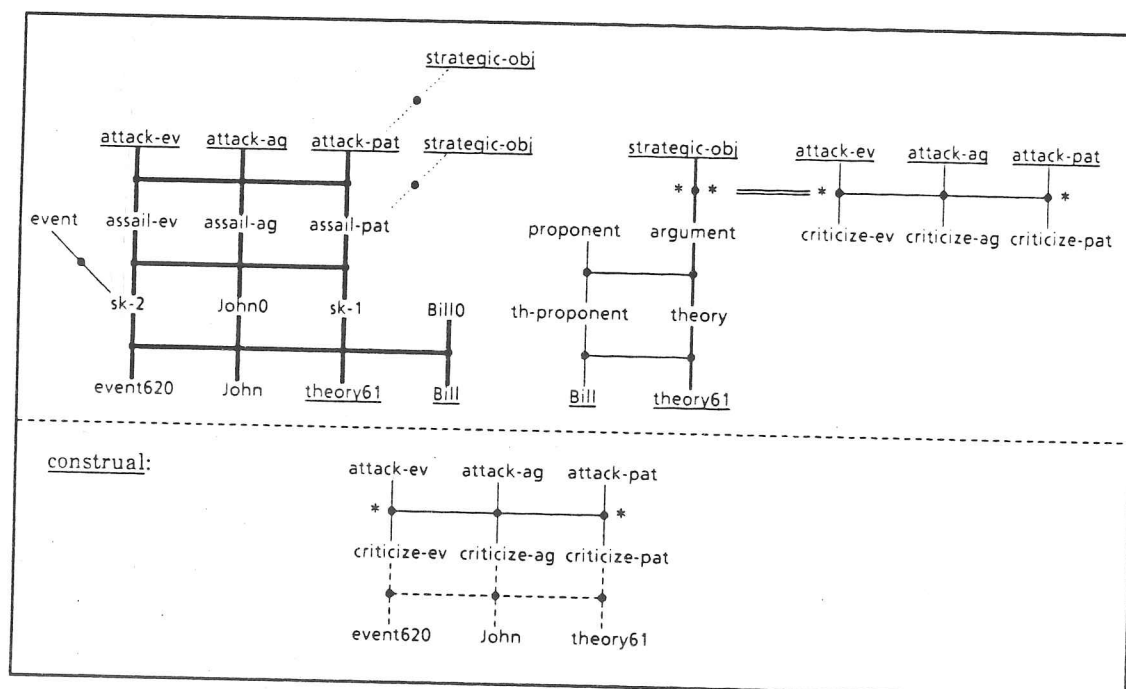


Figure 70: (ATTACK "John" "theory61" "event620")

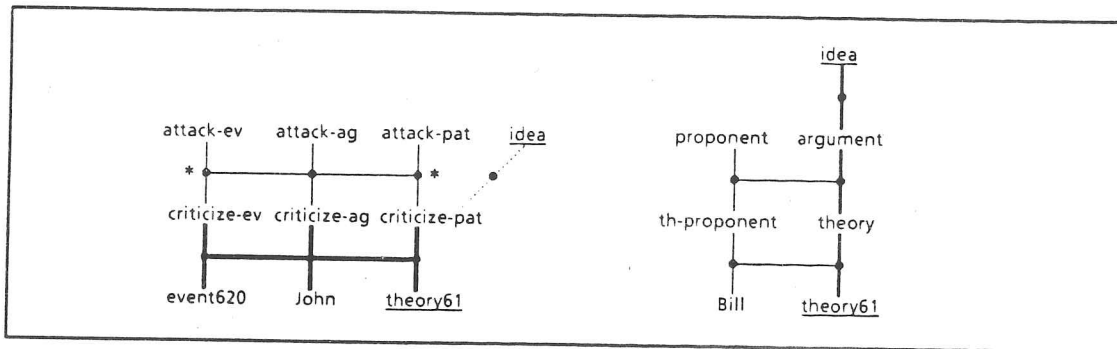


Figure 71: (CRITICIZE "John" "theory61" "event620")

=====

sentence:

(John assailed Bill's theory)
 skolemized indefinite logical form:
 ((ASSAIL "John" "sk-1" "sk-2") (EVENT "sk-2"))
 skolemized definite logical form:
 ((OF "sk-1" "Bill" THEORY) (THEORY "sk-1"))

literal form:

(THEORY "theory61")
 (OF "theory61" "Bill" THEORY)
 (EVENT "event620")
 (CRITICIZE "John" "theory61" "event620")

interpretation acceptable? YES

=====

The output of the system consists of a number of literal logical forms; there is no need to distinguish between definite and indefinite forms, as reference resolution has already been performed. The skolem constants of the input to MINT have been replaced by definite entity names, uniquely identifiable by the application system. Where entities are new to the system, either because they were indefinite in the input or because they have been evoked, they have been given appropriate names; evoked concepts are also mentioned in predications which indicate their relationships to other entities. These literal forms are then accepted or rejected *en bloc*.

More examples are presented in Appendix C, most of which are more complex than the one shown above.

6.8 Summary

This chapter has outlined the operation of MINT in processing both literal and metaphorical input utterances. Input to MINT is in naïve logical form, which is translated into network structures by following rules in a simple lexicon of predicates. After initial reference resolution, processing is achieved by a combination of three major techniques: redescription (including widening and concept evocation), consolidation, and construal. All these techniques can be used during the interpretation of both literal and metaphorical input; metaphor interpretation can be achieved by straightforward abstraction (when redescription throws up well-formed descriptions of the input entities), metaphorical reference resolution, (when metaphorically related entities are introduced into redescription as a result of matching complex argument restrictions, or, in some cases, of consolidation), and construal (where a metaphorically matched argument restriction reveals an appropriate associated d-link).

During matching operations, if more than one match is found, this is interpreted as a choice of interpretations, and these choices are explored depth first. Well-formedness judgements are made relative to the current interpretation, which ensures that the descriptions passed on to the Acceptance Component are consistent with each other. Processing is controlled by means of an agenda.

The result of this processing is a series of interpretations, each consisting of a package of literal logical forms constituting a literal paraphrase of the input. These interpretations are offered one by one to the (simulated) Acceptance Component, until one is accepted according to deep semantic and pragmatic criteria.

The performance of MINT in interpreting metaphors is discussed in the next and final chapter.

7. Discussion

This final chapter is a discussion of descriptonal analogy, how it fits in with previous theories of metaphor, its strengths and weaknesses, and directions for future research. Throughout this discussion it is important to bear in mind the distinction between the *theory* of descriptonal analogy, as presented in chapters 3 and 4, and its *implementation* in the MINT system, as described in chapters 5 and 6. The theory is rather general and leaves many details underspecified, whereas the implementation has filled in the details, but only to a first approximation – deficiencies in the implementation should not be assumed to be deficiencies in the theory, they are indicative of shortcomings in the approximations employed.

Overview

This chapter is divided into four sections. 7.1 discusses the performance of the MINT system. 7.2 discusses issues arising from the implementation of MINT, including possible fruitful directions for further research. 7.3 discusses issues arising from the theory of descriptonal analogy. 7.4 sums up the overall conclusions of the thesis.

7.1 System performance

7.1.1 Examples covered

MINT is successful in dealing with quite a variety of metaphorical input, covering nominal metaphor, such as¹

- (1) *John is a carrier of AIDS*
[*John is infected with AIDS*]

predicative metaphor,

- (2) *John gave Bill an idea*
[*John communicated an idea to Bill*]

and sentential metaphor,

- (3) *John destroyed Bill*
[*John reduced Bill's confidence to nothing*].

¹ English glosses of the paraphrases produced by MINT are given in square brackets.

MINT processes, using the same mechanisms, both firmly established metaphors (involving word senses that might be found in standard dictionaries), such as

- (4) *The price of gold is rising,*
[*The price of gold is increasing*]
- (5) *The crime rate is soaring,*
[*The crime rate is increasing rapidly to a great level*]
- (6) *John felt low,*
[*John's happiness was little*]

and the more original kind (involving metaphorical word senses unlikely to be found in any dictionary), for example

- (7) *Mary poured her sorrow into a letter,*
[*Mary expressed her sorrow in a letter*]
- (8) *John shot down Bill's argument.*
[*John criticized Bill's argument, reducing its convincingness to nothing*]

The following is a list of some of the examples processed by MINT, and on which more details are given in Appendix C. In this list, words interpreted metaphorically are indicated by italics.

MORE IS UP:

The price of eggs is *low*
The temperature is *rising*
The crime rate is *soaring*
The price of petrol is *up*
The price of gold is *higher than* the price of eggs

THE MIND IS A BRITTLE OBJECT,

HAPPINESS IS UP,

FRIENDLINESS IS WARMTH:

John *destroyed* Bill
Bill was *shattered*
Bill was a *broken* man
John felt *down*
John's spirits *rose*
John's spirits *sank*
John was *depressed*
John is a *cold* person

ARGUMENT IS WAR:

John *attacked* Bill's theory
John *shot down* Bill's argument
Bill's argument is *strong*
John's theory is *flimsy*

INFECTING IS GIVING:

John *gave* Mary a virus
Mary *caught* a cold *from* John
Mary *has* flu
John is a *carrier of* AIDS

TOUCHING IS GIVING:

John *gave* Mary a kiss

Mary *sold* John a kiss
John *gave* Mary a smack
Mary *took* a smack *from* John

The conduit metaphor:

IDEAS ARE OBJECTS,
LINGUISTIC EXPRESSIONS ARE CONTAINERS,
EXPRESSING IS PUTTING,
COMMUNICATION IS SENDING:

Bill *put* the idea *into* a letter
The poem was *full of* emotion
The essay was *crammed with* ideas
Mary *poured* her sorrow *into* a letter
John *gave* Bill an idea
Bill *got* his argument *across* to John

In assessing the performance of descriptive analogy in processing these examples, it must be remembered that the extreme methodology was adopted whereby *all* semantic knowledge is represented in analogical form, and *all* word sense disambiguation is done by metaphorical processing. These methodological principles mean that these examples have constituted a severe test of the theory of descriptive analogy in terms of its coverage of both literal and metaphorical linguistic constructions. Experience shows that the theory is well up to coping with these examples, and the most problematic aspect of adding further examples is the usual problem of how to represent the required semantics for the core senses of words.

The real power of systematic metaphor in explaining how polysemous word senses are derived from core senses is perhaps best demonstrated by the MORE IS UP examples. This is because the domain of rising objects is relatively simple, yet well populated with interrelated ideas. These examples seem at first sight to be among the least 'metaphorical' of them all, but a *single* with two metaphorical i-link is what enables MINT to derive suitable interpretations for rising, falling, rocketing, plunging, high, low, up, down, higher, lower, and more besides, given only the physical senses of these words. It is the very fact that these examples seem so commonplace that makes it important to be able to handle them properly – there is a very large number of motion words, and it is almost inconceivable that any dictionary would list an appropriate polyseme for all of them, yet such words are highly likely to crop up in the input to a realistic natural language system.

Looking a little more deeply at the examples listed above, there are a number of significant points to be made.

Abstraction

The examples listed above all involve interpretation which exploits knowledge of systematic metaphors. MINT's processing, however, can still be productive when no suitable systematic

metaphor can be found, since interpretation then becomes straight abstraction, as seen in the last chapter in the case of "my car drinks petrol".

Semantic complexity

Some of the examples above require quite complex semantic representations. This is particularly true in the case of the conduit metaphor, which relies on ideas of meaning, communication, transport, containment and mass nouns. The semantic models used in MINT are in reality rather crude, but effective, and it is significant that MINT (and in particular DREP) is able to integrate all this knowledge without difficulty.

Multiple metaphorical senses

The word 'give' is given three distinct metaphorical senses in addition to its core 'physical transfer' sense, corresponding to the three systematic metaphors INFECTING IS GIVING, TOUCHING IS GIVING, and COMMUNICATION IS SENDING (part of the conduit metaphor). There is no problem of ambiguity between these senses, since they are generated only as required, as a result of the nature of their arguments. In other words, processing is tightly directed, by focusing on relevant parts of the network, mainly as a consequence of the perspective mechanism and the fact that chains on the agenda are firmly anchored to discourse entities.

A more detailed assessment of MINT's strengths and weaknesses is presented in the next section.

7.1.2 Some statistics

The entire MINT system, comprising of some 335 Common Lisp functions, occupies about 200kb as source code. The lexicon contains around 250 predicates and the network consists of about 700 concepts and 450 d-links.

The example at the end of chapter 6 is a very simple example of MINT's processing, greater complexity generally arises from (a) having more than one interpretation, (b) having a greater branching factor among the i-links, (c) having to redescribe to a greater depth before well-formedness is found. (b) is, of course, dependent to an extent on the number of i-links present in the input, but for the most part there is no direct connection between the form of the input and the time required for processing. The above example takes about 45 seconds to process on a (heavily loaded) Xerox 1186 (Dove) workstation and the more elaborate examples in Appendix C take up to 7 minutes. In considering these figures it must be remembered that the system was not written with efficiency as a priority, and so there is

considerable scope for optimization, particularly with regard to caching the results of matching operations, which are the major consumers of processor time.

7.2 The implementation

MINT and DREP together comprise an implementation of descriptive analogy, and as pointed out above, they should be regarded as first approximations to the ideal implementation. Nevertheless, MINT is very successful in dealing with a good variety of metaphorical input, as described above.

This section reviews a number of areas in which this approximation could perhaps be improved, and thus areas suitable for further research.

7.2.1 Semantic coverage

The most obvious restriction imposed on the implementation is the quality of semantic representation in MINT. The coverage of semantic knowledge in MINT was intended to be broad and shallow, so that the general applicability of descriptive analogy could be demonstrated; however there is no doubt that the system would benefit from a greater sophistication in this knowledge.

DREP is a very general formalism intended to be particularly suited to descriptive analogy, and it shares features with formalisms more ambitious in their representational power, features such as multiple perspectives, property inheritance, and structured links. In being so general it makes few semantic commitments, and as a consequence offers little help to the programmer in the form of short cuts for the representation of particular forms of knowledge. An example that springs to mind is event semantics – the event semantics employed in MINT is very simple, and a more detailed account would increase the range of examples that could be tackled. DREP offers no built-in mechanisms that would help in this enterprise, so information about events must be encoded as unexceptional knowledge.

There is no doubt that improvements could be made within the present limitations of the DREP formalism, and perhaps future developments that would be particularly profitable, in terms of increasing the range of examples that MINT could tackle, would be to improve event semantics and the handling of adverbs, and to include a treatment of tense.

The handling of adverbs would be of particular interest in the context of descriptive analogy:

At present, MINT produces different literal paraphrases for

- (9) *The crime rate is rising,*
- (10) *The crime rate is soaring,*

the first is paraphrased as "the crime rate is increasing", or rather its logical form equivalent, and the second to "the crime rate is increasing *rapidly*".² It can be seen from these examples that adverbs have an important part to play in capturing the nuances of a metaphor – although both metaphors would be usefully interpreted as "the crime rate is increasing", the information conveyed by the adverb adds significantly to the interpretation. These nuances might well be the reason a metaphor was used in the first place, as was observed in chapter 2.

This present handling of adverbs is quite straightforward using DREP: an adverb is attached directly to the event variable using an i-link equivalent of (RAPID "soar-ev"). Unfortunately, this treatment is a little crude. Consider the two utterances

- (11) *John led Mary reluctantly*
- (12) *Mary followed John willingly*

which describe the same event, but from different points of view. Clearly it is not acceptable to describe the *event* as reluctant or willing, rather the relationship between the actor and the event is what seems to be at issue.

The semantics of adverbs are notoriously difficult (see, for example [McConnell-Ginet 82]), but a more sophisticated treatment is likely to be possible without modification of the DREP formalism *per se*, and is likely to be most profitable in terms of enhancing the quality of paraphrases produced by MINT.

In addition to such enhancements to the semantic knowledge of MINT, DREP itself could be extended by incorporating treatments of negation and quantification. Such improvements, however, would not be of immediate interest in the study of metaphor.

7.2.2 Well-formedness conditions

Strongly related to the issue of semantic representation is the question of well-formedness conditions. The implementation of well-formedness conditions in MINT is effected by the use of p-links. These p-links often have width one, in which case they correspond roughly to the simple unary sortal restrictions on predicate arguments which are common in computational linguistics. They may on the other hand be more complex, specifying required *relationships* between various arguments of a predicate.

² In fact, "...to a great level" is also part of the second paraphrase, but this is not of direct concern in the present discussion.

This implementation of sortal restrictions, however, can be seen to differ from the standard approach in that there is no distinct hierarchy of sorts; instead of a specific notion of 'sort', normal DREP concepts are used to specify argument restrictions, and whether a particular argument restriction is satisfied or not is determined by matching in the main network. If a literal matching chain is found, the restriction is deemed to be satisfied, if not, then the restriction is violated. This mechanism is much more flexible than the usual approach to sort hierarchies.

It can be seen that the argument restrictions operate by specifying that a description is well-formed provided that the arguments of the description can *literally* be described in the way specified by p-links.³ For example, in the determination of the well-formedness of (RISE "balloon51" "event57") presented at the end of chapter 5, the width 1 p-links require that (EVENT "event57") and (PHYSOB "balloon51") be literal descriptions known to the system.

This specification of argument restrictions as required descriptions is in line with the philosophy underlying descriptonal analogy: entities cannot be said to be of a certain sort in some absolute and objective sense, they can only be said to be *describable* in certain ways (because of analogies with definitive entities), and only certain of these descriptions are accepted as literal by the dictionary.

If no *literal* matching chain can be found for an argument restriction, this could be for one of two reasons – either no match at all was available or only a metaphorical matching chain could be found. In the latter case the metaphorical chain might contain valuable information as to how interpretation can proceed (via widening and / or construal): the matching chain represents an analogy between its sources and its targets, and that analogy is assumed to underlie, at least in part, the original metaphorical description.⁴ This analogy is then used for metaphorical reference resolution or, if there are associated d-links, construal. In this way the well-formedness conditions represented by p-links can be seen to drive the interpretation process in a very real sense. This is only to be expected, since the task of literal paraphrase is a search for well-formedness, and if a description is ill-formed, it is sensible to investigate the cause of the ill-formedness.

It is a reasonable question to ask whether the well-formedness conditions that can be expressed using p-links are adequate for the sort of examples which we might wish to process. Experience shows that p-links are capable of representing the restrictions required in all the examples presented in Appendix C, and it is easy to represent both the conjunction and disjunction of 'sorts'. It is, however, possible to find examples which would not be covered. Such examples depend on negative, rather than positive restrictions. Consider the

³ Matching *literal* chains correspond to literal descriptions of their targets.

⁴ Of course, this is all relative to the current interpretation.

utterance

(13) **The man is a pig*

or, in logical form, (PIG "man71"). What is required here is a way of specifying that a man cannot also be a pig, i.e., a way of encoding knowledge of mutual exclusivity. This problem is, however, common to any system representing sortal restrictions, and not specifically a result of MINT's way of doing things.

7.2.3 Polysemy

As mentioned earlier, MINT adopts the methodological attitude that it should process as much of its input as possible from metaphorical principles. This inevitably means longer processing times for metaphorical word senses that in reality are well established as polysemous senses in English dictionaries; the example given earlier was the sense of 'to rise' meaning 'to increase'. In a more practical system, where processing time is an issue, it would be sensible to represent these polysemous word senses directly, and this could be done easily in MINT using associated d-links and the construal mechanism.

Figure 72 shows how such a polysemous word sense would be defined for 'rise'. The construal mechanism would then pick up this sense whenever a quantity was described as rising,⁵ without processing having to go through additional steps of redescription, as it does at present.

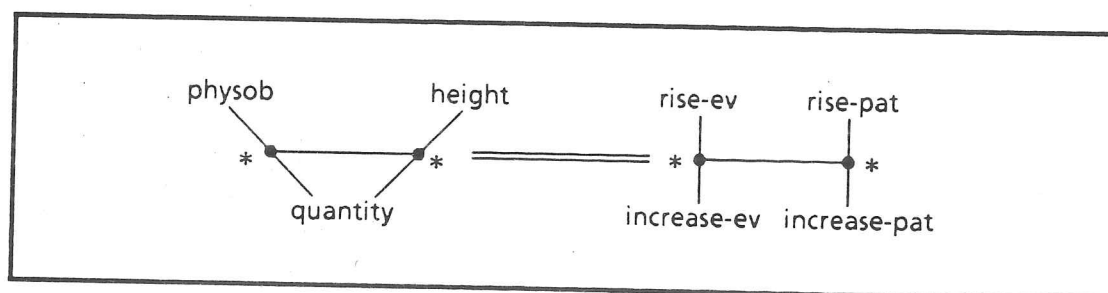


Figure 72: Defining a polysemous sense of 'rise'

It is worth noting that these new i-links representing polysemous senses are perfectly consistent with the semantics of DREP – the new link simply represents the fact that the definitive event of increasing is analogous to the definitive event of rising, or equivalently, increasing can be described as rising.

⁵ Construal would take place because of the p-link specifying the argument restriction of physical object for the patient of rising.

7.2.4 Automatic knowledge acquisition

MINT as it stands offers a fairly broad, but shallow coverage of the various semantic domains it tackles. The coding of the semantic knowledge that enables MINT to process instances of systematic metaphor is a laborious task. Some of the work involves a painstaking formulation of the fundamental concepts in some domain, but much of it is a more straightforward linking together of word senses around these core concepts, in a way that is very close to the surface English. This latter coding of knowledge might well be susceptible to some form of automation.

Already, there is a small suite of 'lexis' functions to make this task easier, so that specifying only that 'soar' implies 'rise' enables the lexis system to create the appropriate i-link linking soar-ev, soar-pat, rise-ev, and rise-pat. It would be very interesting to try to use this sort of approach in conjunction with an on-line dictionary. The *Longman Dictionary of Contemporary English* [Longman 78] would seem to be particularly appropriate for this task, as it is available in machine readable form and its definitions are given in terms of a severely restricted subset of English [Boguraev and Briscoe 89].

As was observed in chapter 1, some word definitions in Longman's (as with other dictionaries) themselves assume the use of systematic metaphor in their interpretation. This observation suggests that MINT's abilities could be put to use in the automated knowledge acquisition task in a sort of bootstrapping operation.

7.2.5 Scale of metaphors

In line with the aims of this thesis, attention has been focused here on how individual words or collocations can be interpreted metaphorically. In other words, MINT's interpretation has been treated as an exercise in lexical semantics – deriving new metaphorical senses for words from knowledge of core word senses and core analogies.

As noted in Chapter 2, however, metaphors can occur on a much larger syntactic scale, indeed, entire books can be regarded as metaphors. Extension of MINT's processing abilities to larger scale metaphors should be feasible as there is no natural size of semantic unit in DREP: word sized semantic units involve up to three or four definitive entities associated in a frame, but frames can be envisaged which are much larger than this, and there is nothing to prevent analogies arising between such large frames. Indeed one can envisage a single very large frame corresponding to Orwell's book *Animal Farm*, with slots corresponding to each of the characters and events. This frame could then be used as the source 'domain' in an analogy with the characters and events of the Russian revolution as targets. Such an analogy, represented by an enormous d-link in MINT, would allow statements about the

entities in *Animal Farm* to be interpreted as statements about entities in the revolution.

7.2.6 Perspectives and interpretations

MINT uses the idea of a perspective to distinguish between different interpretations of an input utterance. The working assumption is that in any single interpretation (a package of literal logical forms) the perspectives on the various entities involved must be consistent.

This requirement for consistency of perspective is of great importance during the process of redescription. For example, when processing

(14) *John was devastated*

there are two competing perspectives on John, viz the physical and the psychological, as outlined in chapter 6. Early in processing, the system makes a choice between these two perspectives, so that (DEVASTATED "John" "state62") is judged ill-formed with respect to the psychological interpretation (in which John is seen only metaphorically as a physical structure). The next stage of redescription comes up with (DESTROYED "John" "state62"), which is also judged ill-formed *with respect to the psychological interpretation*. Thus the inconsistent judgement of one as metaphorical and the other as literal is prevented.

This example demonstrates the importance of maintaining a consistent perspective on a very local level, but it is interesting to consider the implications of this policy when operated on a wider scale, for example across more than one clause in the phenomena of 'mixed' and 'coherent' metaphor.

Mixed metaphors

The consistency of perspective requirement may account for the apparent unacceptability of mixed metaphors.⁶ Consider the example

(15) *?John felt low in his elevated position.*

Here there are two of Lakoff and Johnson's systematic metaphors at work: HAPPY IS UP and HIGH STATUS IS UP. The two metaphors seem to work against each other in that they interpret the metaphorical height of a person in different ways. This would not be allowed with MINT's consistency of perspective requirement. Nevertheless, it is possible to make sense of (15), even if it does sound a little forced, and perhaps there should be a *preference* for consistency, rather than an absolute requirement. It is even possible to find examples that

⁶ This is a more general view of mixed metaphor than the usual clash of idioms.

actually exploit this mixing of perspectives, such as

- (16) *John felt physically and emotionally bruised.*

Coherent metaphors

In mixed metaphor, there is generally some sort of contradictory image which gives rise to infelicity, but it is possible for two metaphors corresponding to different perspectives to sit comfortably together when no actual contradiction arises. Such metaphors are termed 'coherent' in [Lakoff and Johnson 80]. Consider, for example

- (17) *John felt low and frosty.*

This example seems perfectly acceptable, despite the presence of two separate metaphors which both see John as some sort of physical object. MINT avoids the contradiction in this example by combining the two separate metaphors, HAPPY IS UP and FRIENDLY IS WARM, in a single i-link (along with THE MIND IS A BRITTLE OBJECT and INTELLIGENCE IS BRIGHTNESS) as shown in figure 73. This means that all these metaphors are treated as being associated with the same perspective on a person.

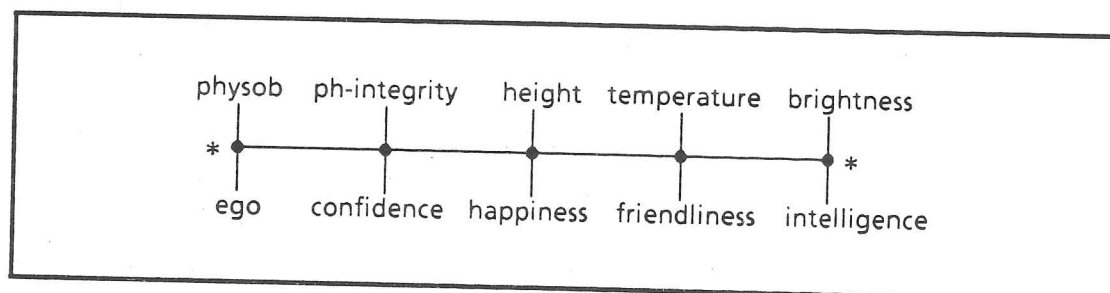


Figure 73: Combining coherent metaphors in a single i-link

There is a deficiency in this approach, however, which is that this is not a 'natural' grouping of systematic metaphors, so while (17) and

- (18) *John felt frosty in his elevated position*

are acceptable, (15) is not. It would seem that coherence of metaphors is not a transitive relation. Clearly a more subtle approach to consistency of perspectives would be a worthwhile area for development in the system.

7.3 The theory of descriptonal analogy

The last section dealt with the computational side of this work, but we finish with a reassessment of the broader theoretical underpinning of MINT – the theory of descriptonal analogy.

7.3.1 Assessment of descriptonal analogy as a theory of metaphor

The theory of descriptonal analogy was developed in the light of a number of observations on metaphor, and descriptonal analogy can perhaps best be seen as a generalization of Black's interaction theory of metaphor as it was described in chapter 2. For convenience Black's own description of his theory is reproduced here:

- (1) A metaphorical statement has two distinct subjects, to be identified as the "primary" subject and the "secondary" one. [these are what have been described here as the target and the source domain]
- (2) The secondary subject is to be regarded as a system [a conceptual domain] rather than an individual thing.
- (3) The metaphorical utterance works by "projecting upon" the primary subject a set of "associated implications," comprised in the implicative complex, that are predicable of the secondary subject. [i.e., implications, or statements, that can be made about the source are applied to the target via some 'projection' mechanism]
- (4) The maker of a metaphorical statement selects, emphasizes, suppresses, and organizes features of the primary subject by applying to it statements isomorphic with the members of the secondary subject's implicative complex. [Since statements about the *source* are applied to the target, the metaphor maker, in his choice of source, effectively selects features of the target to highlight and conversely plays down others]
- (5) In the context of a particular metaphorical statement, the two subjects "interact" in the following ways: (a) the presence of the primary subject incites the hearer to select some of the secondary subject's properties; and (b) invites him to construct a parallel implication-complex that can fit the primary subject; and (c) reciprocally induces parallel changes in the secondary subject [such changes are due to the highlighting and downplaying of source and target features in the hearer's mind].

It can be seen that the mechanisms used in descriptonal analogy correspond well with those described in (3) and (5) and the comments in (4) remain valid. Neither theory involves a formal notion of domain: Black's 'implicative complex' seems deliberately vague and is suggestive of just the sort of implication procedure as is involved in the process of

redescription. A notable difference, though, is that descriptonal analogy is more general in allowing multiple sources and targets.

Recursive processing

The most pertinent difference, though, is the shift in emphasis away from the consideration of a single, isolated metaphor, to combinations of interacting metaphors, or analogies. Descriptonal analogy is seen as operating at a much lower level than was considered in Black's theory, and as a result it is much more pervasive in linguistic processing. Rather than straightforward logical reasoning, this linguistic processing is seen as reasoning with *descriptions*, and since all descriptions are potentially metaphorical, the interpretation process becomes highly recursive. The metaphorical interpretation of intermediate forms would be extremely difficult to justify in a conventional (rather than analogical) setting, and it is precisely this low level, recursive processing that enables descriptonal analogy to deal effectively with systematic metaphor. This contrasts particularly with the semantic marker processing versions of the interaction theory described in chapter 2, where it was seen that the properties represented by markers were too simple, and their atomic nature meant that they were not susceptible to the 'recursive' interpretation process that the evidence of systematic metaphor seems to require.

Literalness

Another observation from chapter 2 that had a strong influence on the theory was that the dividing line between literal and metaphorical processing did not seem at all well defined, and indeed the judgement of whether an individual utterance was literal or metaphorical seemed highly subjective and synchronic – the death of metaphors seemed to involve a smooth transition between metaphoricality and literalness. Metaphor, it seemed, should not be seen as deviant, but as an integral part of natural language. This observation is accounted for very neatly in descriptonal analogy: literalness is seen as a relative term, dependent on a particular dictionary's specifications of well-formedness, and not rooted in any objective and absolute fact. Metaphor is not seen as some bizarre abuse of linguistic resources, it is an integral part of natural language. This is very much in line with George Lakoff's attacks on 'objectivism' in [Lakoff and Johnson 80] and [Lakoff 87], where he sees cultural influences as the primary means of deciding what is literal.

The similarity of literal and metaphorical processing runs very deep in descriptonal analogy. All descriptions are seen as arising through analogy with definitive entities in definitive relationships, and whether they are labelled as literal or metaphorical is a matter of taste, as

determined by the dictionary.⁷ Descriptive analogy, then, can be seen to embrace the thesis of what Cooper called 'the primacy of metaphor', described in chapter 2, whereby metaphorical processes are seen as the normal mode of human thought, and this is reflected in human languages. In the primacy account, a particular chair, say, is not a chair in some fixed and absolute sense, it is merely *described* as a chair because of its similarity with some preconceived notion of the 'ideal' chair – in descriptive analogy, this similarity is indicated by the existence of an analogy with definitive entities.

7.3.2 Coverage of metaphor

As pointed out above, descriptive analogy is unusual among theories of metaphor in considering metaphor to operate on a very low level in linguistic processing. This low level pervasiveness of metaphor and the corresponding prevalence of analogy in linguistic matters, fits in very well with the observation that metaphor seems to occur at all levels of discourse, from the simplest nominal reference, through predication and sentences to entire books.

The theory of descriptive analogy goes much further than the interaction theory in describing how metaphors can be interpreted by relating them to previously known metaphors, or rather analogies. These analogies may have been encountered in the current discourse (in which case we are dealing with *extended* metaphor) or they may be drawn from general knowledge (in which case we are dealing with *systematic* metaphor).

Descriptive analogy however, in common with the interaction theory, does not say very much about how a metaphor can be interpreted from scratch, that is, without reference to prior knowledge of some appropriate analogy. In such cases the only mechanism available seems to be that of abstraction. The abstraction process, though useful, is in itself rather unreliable and it should be controlled by a mechanism which makes use of deep semantic and pragmatic knowledge.⁸ Nevertheless, such metaphors are potentially the precursors of extended metaphors and even (on a longer time scale) systematic metaphors – they involve the same analogical mechanisms and so can be seen to operate within the framework of descriptive analogy. This is clearly an area suitable for further research.

Poetic metaphors are often held up by philosophers as evidence that there is something deeply mysterious and holistic about metaphor, that is lost in any attempt at literal

⁷ In MINT, literal and metaphorical i-links are treated alike, except when it comes to deciding which descriptions pass on as output.

⁸ Pragmatic and semantic notions such as 'salience' and 'importance' are typical in attempts to provide such a mechanism, but they seem a bit simplistic.

There are some treatments of analogy, such as the Structure Mapping Theory [Gentner 89], [Falkenhainer *et al.* 89], and the computational system ACME [Holyoak and Thagard 89], which attempt to deduce analogies from chiefly *syntactic* knowledge. These, however, appear to be heavily dependent on fortuitous choice of syntactic representations, and in particular the characteristic syntactic structures arising from semantic relationships, such as cause and effect.

paraphrase (for example [Davidson 78]). Descriptive analogy should not be seen as incompatible with this view, as one of its basic premises is that metaphorical descriptions are perfectly valid as descriptions, and it is the analogies underlying them that carry the holistic message. It is only when a literal paraphrase is required, for example by a poetically unappreciative computer application, that it is necessary to resort to pulling the metaphor apart, thereby losing some of the effect of the original wording. Descriptive analogy *per se* does not deny the possibility of 'perlocutionary' effects, but its implementation in MINT does not cater for this, as it insists on producing a literal paraphrase, and on top of that, its semantic representations are rather shallow so that many of the rich semantic associations that otherwise might be generated are simply not represented.

7.3.3 Lexical semantics

Descriptive analogy is a theory about lexical semantics. The knowledge handled by the theory lies very close to surface language, and this is due to the emphasis on definitive entities, which have a habit of being strongly associated with English words via their intrinsic descriptions – relationships between definitive entities mirror the relationships between words in a way that closely resembles the conventional lexicographical practice of defining words in terms of other words. The most notable difference between the approach of descriptive analogy and that of dictionary writers is the distinction made between *core* senses of words and derived senses.

Early on in this thesis it was proposed that a significant number of metaphorical word senses could be deduced from a knowledge of the core senses of words and a knowledge of the core analogies underlying systematic metaphors. Descriptive analogy has lived up to this early promise in that such metaphorical word senses can be derived from core senses and core analogies 'on the fly'. There is no reason at all why these metaphorical senses should not be remembered for later reference, effectively 'fleshing out' the initially skeletal dictionary (indeed a mechanism for doing just this in the MINT system would be easy to implement, as outlined previously).

7.3.4 Other tropes

A number of observations can be made on just what sort of phenomena can be addressed by the theory of descriptive analogy. For example, does descriptive analogy have anything to say about the various tropes discussed in chapter 2, and does descriptive analogy shed any light on the problem of classifying tropes?

Simile

Simile is a trope that is often seen as either profoundly different from metaphor or profoundly similar. It was seen in chapter 2 that metaphors can often, if not always concisely, be rewritten as similes, and indeed this is the thesis of the comparison theory of metaphor in its various forms. Descriptive analogy too sees a (complex) similarity, or analogy, as being behind a metaphor, and so on a *semantic* level similes and metaphors appear indistinguishable. There seems to be little *semantic* difference between

(19) *Sally is a block of ice*

(20) *Sally is like a block of ice,*

except, perhaps that (20) seems to include an additional assertion that Sally is not literally a block of ice. There is however an obvious *syntactic* difference, in that the latter contains a prepositional phrase, and furthermore there would seem to be a *pragmatic* difference in that the metaphor seems somehow more forceful, it has a greater perlocutionary effect.

This observation would suggest that descriptive analogy could interpret similes as 'explicitly labelled' metaphors.

Idiom

Many examples of idiom can be seen to be based on metaphor, and indeed on systematic metaphor, for example, the idioms

(21) *through the roof*

(22) *over the moon*

are manifestations of the MORE IS UP and HAPPY IS UP metaphors respectively.

It is characteristic of idioms that they are not compositional, in that their full meaning cannot be deduced solely from their constituent words, but the application of systematic metaphorical interpretation would seem to offer a very real chance of recovering a partial meaning, and so descriptive analogy would apply.⁹

Irony, hyperbole, litotes, and negation

Descriptive analogy does not say much about these phenomena, but it can be seen that all of them may occur in conjunction with, or 'on top' of, metaphor. All these phenomena can be seen to *modify* a basic substrate of meaning, and it sometimes happens that this substrate

⁹ There has been some computational research by Uri Zernik along the lines of interpreting idioms as metaphors. See [Zernik 87].

needs to be determined by metaphorical interpretation. Examples would be, respectively,

- (23) *Like hell the value of my house is rising!*
- (24) *The housing market has completely collapsed!*
- (25) *Stock prices fell a bit on 'Black Monday'.*
- (26) *The crime rate is not falling.*

The moral of these examples would seem to be that metaphorical processing is involved at an early stage of linguistic processing, perhaps in association with conventional word sense disambiguation (which is still required to deal with homonymy). This is again consistent with the philosophy behind descriptonal analogy.

7.3.5 Metonymy

Metonymy is a trope that has sometimes been included under the title of metaphor, Aristotle's definition of metaphor as "giving a thing a name that belongs to something else", for example, definitely includes metonymy. Descriptonal analogy, however, asserts that metaphorical language is the result of perceived similarities between sources and targets, and metonymy manifestly does not arise out of similarity. For example, calling the Washington administration 'Washington' does not rely on any similarity between the city and the administration, it simply relies on their association.¹⁰

Metonymy, however, shares some interesting properties with metaphor, and in particular, systematic patterns of metonymy can be identified analogous to the systematic patterns of metaphor addressed by descriptonal analogy. Some examples are CONTROLLER FOR CONTROLLED, as in

- (27) *Bush invaded Panama*

and PRODUCER FOR PRODUCT, as in

- (28) *The orchestra played Vivaldi.*

These patterns of metonymy are discussed in some detail in [Lakoff and Johnson 80] and are handled computationally in Dan Fass's Meta5 program [Fass 86a, 86b, 88a].

Another parallel with metaphor, and a feature that is particularly significant in descriptonal analogy, is that metonymy seems to be a great deal more pervasive in language than is immediately apparent. Metonymy too has both striking forms, and forms that pass completely unnoticed in conversation. For example, names can be seen as being used in a NAME FOR PERSON metonymy: when the word 'John' is used, it can be interpreted as 'the person whose name is John'. James Pustejovsky has developed the notion of 'logical metonymy' to explain certain common phenomena in lexical semantics [Pustejovsky 89] and

¹⁰ See, for example, [Fass 88b].

Jerry Hobbs finds it useful to assume the existence of metonymy in the input to his TACITUS system [Hobbs and Martin 87]. It would appear that metaphor and metonymy interpretation should occur in the same phase of processing, i.e., prior to considerations of irony, hyperbole, negation, *etc.* It would be a very interesting topic for research to attempt an integrated, low level treatment of metaphor *and* metonymy.

7.4 Conclusions

This thesis has argued that, far from being a bizarre aberration of language, metaphor should be seen as extremely common and a fundamental part of the linguistic process, both synchronically in the utterance of new metaphors and diachronically in word sense formation. Indeed the distinction between literal and metaphorical utterances should not be seen as an absolute distinction, but rather as a relative phenomenon, dependent upon the tastes of a hearer. In the context of a natural language processing system, however, where there can be a strong notion of well-formedness imposed by what is *meaningful* to some computer application, the distinction between literal and metaphorical becomes clear cut, and it becomes a necessity to be able to detect and interpret metaphorical utterances.

The problems involved in interpreting some metaphors can be severe, and large amounts of deep semantic and pragmatic knowledge would be called for. It is possible, however, to discern large scale patterns in metaphorical language, where many established and novel metaphors are seen to be extensions of a number of 'core' metaphors – this is the phenomenon of 'systematic' metaphor. It has been argued that systematic metaphor is likely to be well represented in the input to practical natural language processing systems, and that storing core metaphors as dictionary-like entries would enable the interpretation of such input. This interpretation might fall short of perfection, but would nevertheless be useful.

The theory of descriptonal analogy developed here explains how metaphors arise from perceived analogies and how such analogies can be seen to operate at a very low level in linguistic representation. It is successful in accounting for many empirical observations of metaphor and is consistent with the so-called primacy theory, in which all linguistic expression is seen as metaphorical. The theory represents a significant improvement on previous theories, which have generally considered metaphors only in isolation. The consideration of metaphors in the context of other metaphors and analogies is what enables descriptonal analogy to explain the phenomena of extended and systematic metaphor.

The MINT system was devised as an implementation of the principles of descriptonal analogy, having at its heart the DREP representation formalism, which represents semantic knowledge exclusively as a network of analogies, an approach which brings with it some real advantages over more conventional semantic networks. The system represents a single

'core' sense for each word and attempts to process polysemous senses of words as instances of systematic metaphor. MINT successfully produces literal paraphrases of many examples of systematic metaphor, both established and novel, and can handle literal input using precisely the same mechanisms. This is a significant demonstration of the power of descriptive analogy in giving an integrated account of both literal and metaphorical language, and also of the effectiveness with which systematic metaphor can be handled computationally.

Appendix A: Glossary

c-entity

A 'conversational entity' – any mental object that can be talked about.

dead metaphor

See metaphor.

domain

An informal subject area.

established metaphor

A less pejorative term for 'dead metaphor'. See metaphor.

extended metaphor

See metaphor.

Grice's maxims of conversation

These four maxims are said to govern cooperative conversation:

Quality – be truthful

Quantity – say no more or less than required

Relevance – be relevant

Manner – be perspicuous.

hyperbole

Hyperbole is overstatement, as in

- (1) *For the millionth time, stop exaggerating!*
- (2) *Dick is a genius (when Dick is merely clever)*

idiom

Idiom is the use of a group of words with an accepted meaning which is not readily understood in terms of the meanings of the individual words. Many idioms have their roots in metaphor.

- (3) *He kicked the bucket*
- (4) *They buried the hatchet*
- (5) *It was over the top*

irony

Irony is saying one thing and meaning the opposite, for example

- (6) *Thanks a lot (said after being offered no help)*
- (7) *But he plays so well! (said of a bad chess player)*

literal

Technically (in this thesis), an utterance is literal (with respect to a dictionary) if it is well-

formed and its dictionary meaning is the meaning intended by the speaker.

litotes

Litotes is understatement as in

- (8) *That didn't go too badly (after winning a match)*
- (9) *GEC has a few pounds to spare.*

metaphor

A figure of speech whereby one c-entity (the 'target') is described as if it were another (the 'source'), and this description is justified by some perceived similarity, or analogy (the 'underlying analogy'), between the two. 'Metaphor' is the general phenomenon, whereas 'a metaphor' is an actual piece of text or utterance. In general, there may be more than one source and target in a metaphor.

When a metaphor becomes sufficiently familiar to appear in dictionaries it is called a 'dead' or 'established' metaphor. This is in contrast to 'novel' metaphors, which are generally unfamiliar (the distinction between established and novel metaphors is not clear-cut).

The phenomenon of 'extended metaphor' occurs when the analogy underlying one metaphor is re-used and elaborated in subsequent metaphors in the same discourse or text. The phenomenon of 'systematic metaphor' is seen to rely on a common analogy underlying many individual metaphors which may come from entirely separate texts. Each such pattern of metaphors is called 'a systematic metaphor', and these are given mnemonic labels conventionally written in capitals. Examples of systematic metaphors are given in Appendix B. A metaphor that can be seen to come under the umbrella of one of these systematic metaphors is called a 'manifestation' of that systematic metaphor. The common analogy underlying the manifestations of a systematic metaphor is called its 'core analogy'.

metonymy

Metonymy is the reference to some c-entity by some related c-entity, as in

- (10) *Washington is angry with the Kremlin (the respective administrations)*
- (11) *John played Mozart (Mozart's music)*
- (12) *England beat Australia in the third test (the respective cricket teams)*
- (13) *Reagan invaded Grenada (Reagan's troops)*

What distinguishes metonymy from metaphor is that the former does not indicate any similarity or comparison between the two c-entities, it merely uses one c-entity as a label for the other.

novel metaphor

See metaphor.

simile

The explicit comparison of two c-entities, typically involving the words 'like' or 'as':

- (14) *Education is like shepherding,*
- (15) *The proposed extension to the National Gallery is like a monstrous carbuncle on the face of a much loved friend,*

(16) *John is cunning as a fox.*

source

A c-entity involved in a metaphor (or analogy). See metaphor.

source domain

The domain of the sources of a metaphor (or analogy).

target

A c-entity involved in a metaphor (or analogy). See metaphor.

target domain

The domain of the targets of a metaphor (or analogy).

systematic metaphor

See metaphor.

trope

A 'figure of speech', such as simile, metaphor, metonymy, idiom, hyperbole, litotes, irony.

well-formed

Technically (in this thesis), an utterance is semantically well-formed (with respect to some dictionary) if it is possible that words are being used in their dictionary senses.

Appendix B: Some Examples of Systematic Metaphors

These examples have been collected from a number of sources, the one deserving special mention being *Metaphors we live by* [Lakoff and Johnson 80] where many more examples can be found.

(1) MORE IS UP:

Population is *up* / *down* / *rising* / *falling* / *soaring* / *plummeting*

High fidelity, *low* resolution, *peak* performance

A *steep* temperature *gradient*

Prices *have fallen through the floor*

Harry *raised* his bid

House prices *have risen out of reach of* the first time buyer.

(2) TIME IS A MOVING OBJECT:

In the *following* weeks...

In the *preceding* days...¹

The time *will come*...

The time *has arrived*

The hours *passed* / *crept* / *crawled* / *dragged* / *sped* / *whizzed by*.

(3) THE MIND IS A BRITTLE OBJECT:

Her ego is very *fragile*.

You have to *handle* him *with care*.

He *broke* under cross-examination.

The experience *shattered* him.

Queen Victoria was *made of iron*.

(4) UNDERSTANDING IS SEEING

IDEAS ARE LIGHT SOURCES

DISCOURSE IS A LIGHT MEDIUM:

I *see* what you're saying.

It *looks* different from my *point of view*.

Now I've got the *picture*.

Let me *point something out* to you.

That was a *brilliant* remark.

He is *blind* to the *blinding* truth.

The argument is *clear*.

¹ It is arguable whether 'preceding' should be considered primarily as a temporal word or a spatial word. 'Before' is a word that is similarly ambiguous.

The discussion was *opaque*.

(5) ARGUMENT IS WAR:

Your claims are *indefensible*.

He *attacked* every *weak point* in my argument.

His criticisms were *right on target*.

I *demolished* his argument.

I've never *won* an argument with him.

You disagree? Okay, *shoot*!

If you use that *strategy*, he'll *wipe you out*.

He *shot down* all of my arguments.

(6) AN ARGUMENT IS A CONTAINER:

Your argument is *full of holes*.

It has no *content*.

There are some good ideas *in* that argument.

(7) AN ARGUMENT IS A JOURNEY:

We *set out* to show...

So far, we have...

We *proceed step-by-step*.

Are you *with me*?

We're *going round in circles*.

We shall *return to this point* later.

We are now *in a position* to see that...

I'm *lost*!

(8) AN ARGUMENT IS A BUILDING:

A *well structured* argument.

Little *supporting* evidence.

His argument *collapsed*.

(9) The Conduit Metaphor: [Reddy 79]

IDEAS ARE OBJECTS

LINGUISTIC EXPRESSIONS ARE CONTAINERS

COMMUNICATION IS SENDING:

Try to *get* your thoughts *across* better.

You still haven't *given* me any idea of what you mean.

He has *accepted* my argument.

Whenever you have a good idea practise *capturing* it in words.

Try to *pack* more thoughts *into* fewer words.

The sentence was *filled* with emotion.

Your words are *hollow* – you don't mean them.

(10) A PROBLEM IS A SOLID OBJECT:

a *hard* problem

a *soft* problem

to *scratch the surface* of a problem

to *get into* this problem

hidden *deep within* the problem ...²

on the surface it looks easy

an *impenetrable* problem

to *open up* a problem

(11) METAPHORS ARE LIVING THINGS:

dead / live metaphors

dead metaphors can show *signs of life*

to make a metaphor is to *murder* it³

this is just the *corpse* of a metaphor

a *fossilized* metaphor

² c.f. UNDERSTANDING IS SEEING

³ [Davidson 78] p. 32.

Appendix C: Some Examples of MINT's Processing

This appendix gives examples of MINT's processing of input metaphors. These examples are divided into illustrations of six systematic metaphors,¹ although there are some that involve more than one at a time. The systematic metaphors and their manifestations processed are as follows [italics indicate the words used metaphorically]:

MORE IS UP:

The price of eggs is *low*
The temperature is *rising*
The crime rate is *soaring*
The price of petrol is *up*
The price of gold is *higher than* the price of eggs

THE MIND IS A BRITTLE OBJECT: etc.

John *destroyed* Bill
Bill was *shattered*
Bill was a *broken* man
John felt *down*
John's spirits *rose*
John's spirits *sank*
John was *depressed*
John is a *cold* person

ARGUMENT IS WAR:

John *attacked* Bill's theory
John *shot down* Bill's argument
Bill's argument is *strong*
John's theory is *flimsy*

INFECTING IS GIVING:

John *gave* Mary a virus
Mary *caught* a cold *from* John
Mary *has* flu
John is a *carrier of* AIDS

TOUCHING IS GIVING:

John *gave* Mary a kiss
Mary *sold* John a kiss
John *gave* Mary a smack
Mary *took* a smack *from* John

The conduit metaphor:

Bill *put* the idea *into* a letter
The poem was *full of* emotion
The essay was *crammed with* ideas
Mary *poured* her sorrow *into* a letter
John *gave* Bill an idea
Bill *got* his argument *across* to John

In each case, the input is supplied to MINT in logical form (as described in chapter 6) and MINT produces a number of interpretations (collections of logical forms) until one is found which is acceptable to the user – this is usually the first one.

¹ Many of these, however, are complex associations of more than one analogy.

The processing undertaken by MINT is summarized in the following form:

```
=====
sentence:
  (input sentence)
skolemized indefinite logical form:
  (indefinite conjuncts)
skolemized definite logical form:
  (definite conjuncts)
-----
evoked-concepts:
  list of evoked concepts for first interpretation

literal form:
  list of literal logical forms for first interpretation

[English gloss of interpretation]

Interpretation acceptable? NO
-----
evoked-concepts:
  list of evoked concepts for second interpretation

literal form:
  list of literal logical forms for second interpretation

[English gloss of interpretation]

Interpretation acceptable? YES
=====
```

Summaries of inputs are separated by rows of = signs, a double row indicating the start of a new 'discourse', a single row indicating a continuation of the same 'discourse'.²

² A 'discourse' generally consists of an input to set up some discourse entities followed by a metaphorical input making use of these entities.

1. MORE IS UP

The MORE IS UP metaphor is probably the simplest in form used by MINT, but the most useful, in that it frequently crops up in manifestations of other systematic metaphors. The core analogy, as represented in the network, is shown in figure 1. A rough summary of this analogy is 'a quantity can be described as a physical object (that goes up and down), provided its height is interpreted as the quantity itself'.

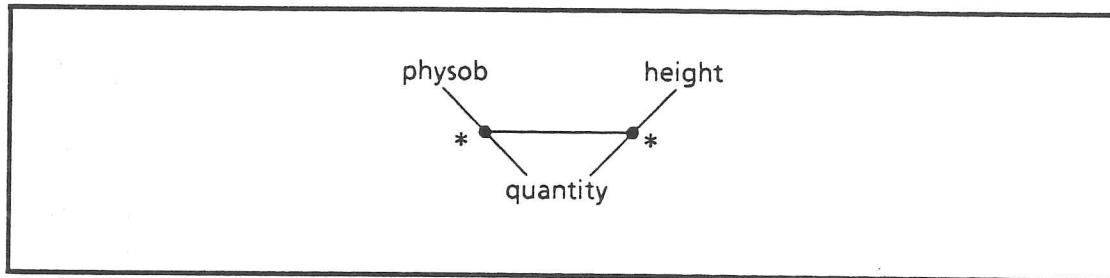


Figure 1: MORE IS UP

This analogy is used in conjunction with other knowledge in the network, such as the fact that a low object has little height and a high object has great height (these are seen as the core senses of 'low' and 'high').

The predicates LITTLE and GREAT are assumed to apply literally to quantities, as are LESSER and GREATER. The simple event semantics employed in some of these examples is that events can lead to 'consequent' states, and conversely states result from 'antecedent' events. Other predicates should be self-explanatory.

=====

sentence:

(the price of eggs is low)

skolemized indefinite logical form:

((LOW "sk-anon1" "sk-anon2") (STATE "sk-anon2"))

skolemized definite logical form:

((PRICE "sk-anon1") (OF "sk-anon1" "eggs" PRICE))

evoked-concepts:

"price0"

literal form:

(STATE "state0")

(OF "price0" "eggs" PRICE)

(LITTLE "price0" "state0")

[The price of eggs is little]

Interpretation acceptable? YES

=====

```
=====
sentence:
  (a temperature)
skolemized indefinite logical form:
  ((TEMPERATURE "sk-anon1"))
skolemized definite logical form:
  NIL
-----
```

evoked-concepts:

```
literal form:
  (TEMPERATURE "temperature0")
```

[This sets up a referent for next example]

Interpretation acceptable? YES

```
=====
```

```
sentence:
  (the temperature is rising)
skolemized indefinite logical form:
  ((RISE "sk-anon1" "sk-anon2") (EVENT "sk-anon2"))
skolemized definite logical form:
  ((TEMPERATURE "sk-anon1"))
-----
```

evoked-concepts:
"conseq-state0"

```
literal form:
  (EVENT "event0")
  (OF "conseq-state0" "event0" CONSEQUENT-ST)
  (INCREASED "temperature0" "conseq-state0")
  (INCREASE "dummy=" "temperature0" "event0")
```

[The temperature is increasing / is increased]

Interpretation acceptable? YES

```
=====
```

```
=====
sentence:
  (the crime rate is soaring)
skolemized indefinite logical form:
  ((SOAR "sk-anon1" "sk-anon2") (EVENT "sk-anon2"))
skolemized definite logical form:
  ((RATE "sk-anon1") (OF "sk-anon1" "crime" RATE))
-----
```

evoked-concepts:
"conseq-state0" "rate0"

```
literal form:
  (EVENT "event0")
  (OF "conseq-state0" "event0" CONSEQUENT-ST)
  (RAPID "event0")
  (OF "rate0" "crime" RATE)
  (GREAT "rate0" "conseq-state0")
  (INCREASE "dummy=" "rate0" "event0")
  (INCREASED "rate0" "conseq-state0")
```

[The crime rate is increasing rapidly to a great level]

Interpretation acceptable? YES

```
=====
```



```
=====
sentence:
  (the price of petrol is up)
skolemized indefinite logical form:
  ((UP "sk-anon1" "sk-anon2") (STATE "sk-anon2"))
skolemized definite logical form:
  ((PRICE "sk-anon1") (OF "sk-anon1" "petrol" PRICE))
-----
```

```
evoked-concepts:
  "anteced-event0" "price0"
```

```
literal form:
  (STATE "state0")
  (OF "anteced-event0" "state0" ANTECEDENT-EV)
  (OF "price0" "petrol" PRICE)
  (INCREASED "price0" "state0")
  (INCREASE "dummy=" "price0" "anteced-event0")
```

[The price of petrol is increased
(a result of a prior increasing event)]

Interpretation acceptable? YES

```
=====
```

```
=====
sentence:
  (the price of gold is higher than the price of eggs)
skolemized indefinite logical form:
  ((HIGHER "sk-anon1" "sk-anon2" "sk-anon3") (STATE "sk-anon3"))
skolemized definite logical form:
  ((PRICE "sk-anon1") (OF "sk-anon1" "gold" PRICE)
   (PRICE "sk-anon2") (OF "sk-anon2" "eggs" PRICE))
-----
```

```
evoked-concepts:
  "price1" "price0"
```

```
literal form:
  (STATE "state0")
  (OF "price1" "gold" PRICE)
  (OF "price0" "eggs" PRICE)
  (LESSER "price0" "price1" "state0")
  (GREATER "price1" "price0" "state0")
```

[The price of gold is greater than the price of eggs]

Interpretation acceptable? YES

```
=====
```

2. THE MIND IS A BRITTLE OBJECT etc.

The examples in this section are based around the group of coherent systematic metaphors

THE MIND IS A BRITTLE OBJECT

HAPPY IS UP

FRIENDLINESS IS WARMTH

These analogies underlying these metaphors are represented as a single metaphorical i-link in DREP as shown in figure 2.

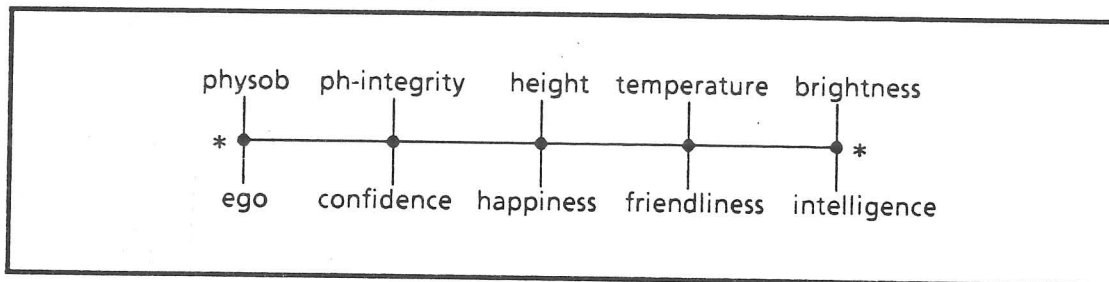


Figure 2: THE MIND IS A BRITTLE OBJECT etc.

Most of these examples have (at least) two possible interpretations, since they can be interpreted literally as well as metaphorically. The heuristics employed in MINT favour the literal interpretations and so the first interpretation must be rejected before the desired metaphorical interpretation is found.

The predicates used in these examples are self-explanatory, but a point to mention is that 'spirits' and 'confidence' are treated as exact synonyms, as are 'happiness' and 'joy'.

=====

sentence:
 (John destroyed Bill)
skolemized indefinite logical form:
 ((DESTROY "John" "Bill" "sk-anon1") (EVENT "sk-anon1"))
skolemized definite logical form:
 NIL

evoked-concepts:
 "physob-integrity0" "conseq-state0"

literal form:
 (EVENT "event0")
 (OF "conseq-state0" "event0" CONSEQUENT-ST)
 (DESTROY "John" "Bill" "event0")
 (DESTROYED "Bill" "conseq-state0")
 (PHYSOB "Bill")
 (OF "physob-integrity0" "Bill" P-INTEGRITY)

[John physically destroyed Bill (consequence: Bill is destroyed)]

Interpretation acceptable? NO

evoked-concepts:
 "confidence0" "conseq-state0"

literal form:
 (EVENT "event0")
 (OF "conseq-state0" "event0" CONSEQUENT-ST)
 (REduced-TO-NOTHING "confidence0" "conseq-state0")
 (REduce-TO-NOTHING "John" "confidence0" "event0")
 (OF "confidence0" "Bill" SPIRITS)
 (OF "confidence0" "Bill" CONFIDENCE)
 (CONFIDENCE "confidence0")

[John reduced Bill's confidence to nothing]

Interpretation acceptable? YES

=====

```
=====
sentence:
  (Bill was shattered)
skolemized indefinite logical form:
  ((SHATTER "=dummy=" "Bill" "sk-anon1") (EVENT "sk-anon1"))
skolemized definite logical form:
  NIL
```

```
-----
evoked-concepts:
```

```
literal form:
  (EVENT "event0")
  (SHATTER "=dummy=" "Bill" "event0")
```

```
[Bill was physically shattered]
```

```
Interpretation acceptable? NO
```

```
-----
evoked-concepts:
  "confidence0" "conseq-state0"
```

```
literal form:
  (EVENT "event0")
  (OF "conseq-state0" "event0" CONSEQUENT-ST)
  (REDUCED-TO-NOTHING "confidence0" "conseq-state0")
  (REDUCE-TO-NOTHING "=dummy=" "confidence0" "event0")
  (OF "confidence0" "Bill" SPIRITS)
  (OF "confidence0" "Bill" CONFIDENCE)
  (CONFIDENCE "confidence0")
```

```
[Bill's confidence was reduced to nothing]
```

```
Interpretation acceptable? YES
=====
```

=====

sentence:
 (Bill was a broken man)
skolemized indefinite logical form:
 ((BROKEN "Bill" "sk-anon1") (MAN "Bill") (STATE "sk-anon1"))
skolemized definite logical form:
 NIL

evoked-concepts:
 "anteced-event0"

literal form:
 (MAN "Bill")
 (STATE "state0")
 (OF "anteced-event0" "state0" ANTECEDENT-EV)
 (BROKEN "Bill" "state0")
 (BREAK "=dummy=" "Bill" "anteced-event0")

[Bill was physically broken]

Interpretation acceptable? NO

evoked-concepts:
 "confidence0" "anteced-event0"

literal form:
 (MAN "Bill")
 (STATE "state0")
 (OF "anteced-event0" "state0" ANTECEDENT-EV)
 (REduced-TO-NOTHING "confidence0" "state0")
 (REDUCE-TO-NOTHING "=dummy=" "confidence0" "anteced-event0")
 (OF "confidence0" "Bill" SPIRITS)
 (OF "confidence0" "Bill" CONFIDENCE)
 (CONFIDENCE "confidence0")

[Bill's confidence was reduced to nothing]

Interpretation acceptable? YES

=====

```
=====
sentence:
  (John felt down)
skolemized indefinite logical form:
  ((DOWN "John" "sk-anon1") (STATE "sk-anon1"))
skolemized definite logical form:
  NIL
-----
```

```
evoked-concepts:
  "anteced-event0"
```

```
literal form:
  (STATE "state0")
  (OF "anteced-event0" "state0" ANTECEDENT-EV)
  (DOWN "John" "state0")
  (FALL "John" "anteced-event0")
```

[Bill was physically down (the result of a fall)]

Interpretation acceptable? NO

```
-----
evoked-concepts:
  "happiness0" "anteced-event0"
```

```
literal form:
  (STATE "state0")
  (OF "anteced-event0" "state0" ANTECEDENT-EV)
  (DECREASED "happiness0" "state0")
  (DECREASE "happiness0" "anteced-event0")
  (OF "happiness0" "John" HAPPINESS)
  (OF "happiness0" "John" JOY)
  (HAPPINESS "happiness0")
```

[Bill's happiness was decreased]

Interpretation acceptable? YES

```
=====
sentence:
  (John's spirits rose)
skolemized indefinite logical form:
  ((RISE "sk-anon1" "sk-anon2") (EVENT "sk-anon2"))
skolemized definite logical form:
  ((OF "sk-anon1" "John" SPIRITS))
-----
```

```
evoked-concepts:
  "conseq-state0" "confidence0"
```

```
literal form:
  (EVENT "event0")
  (OF "confidence0" "John" SPIRITS)
  (OF "confidence0" "John" CONFIDENCE)
  (OF "conseq-state0" "event0" CONSEQUENT-ST)
  (INCREASE "=dummy=" "confidence0" "event0")
  (INCREASED "confidence0" "conseq-state0")
```

[John's confidence was increased]

Interpretation acceptable? YES

```
=====
sentence:
  (John's spirits sank)
skolemized indefinite logical form:
  ((SINK "sk-anon1" "sk-anon2") (EVENT "sk-anon2"))
skolemized definite logical form:
  ((OF "sk-anon1" "John" SPIRITS))
-----
```

```
evoked-concepts:
  "conseq-state0" "confidence0"
```

```
literal form:
  (EVENT "event0")
  (OF "confidence0" "John" SPIRITS)
  (OF "confidence0" "John" CONFIDENCE)
  (OF "conseq-state0" "event0" CONSEQUENT-ST)
  (DECREASED "confidence0" "conseq-state0")
  (DECREASE "confidence0" "event0")
```

[John's confidence was decreased]

Interpretation acceptable? YES

```
=====
```

```
=====
sentence:
  (John was depressed)
skolemized indefinite logical form:
  ((DEPRESSED "John" "sk-anon1") (STATE "sk-anon1"))
skolemized definite logical form:
  NIL
-----
```

```
evoked-concepts:
```

```
literal form:
  (STATE "state0")
  (DEPRESSED "John" "state0")
```

[John was physically depressed]

Interpretation acceptable? NO

```
-----
```

```
evoked-concepts:
  "happiness0" "anteced-event0"
```

```
literal form:
  (STATE "state0")
  (OF "anteced-event0" "state0" ANTECEDENT-EV)
  (DECREASED "happiness0" "state0")
  (DECREASE "happiness0" "anteced-event0")
  (OF "happiness0" "John" HAPPINESS)
  (OF "happiness0" "John" JOY)
  (HAPPINESS "happiness0")
```

[John's happiness was decreased]

Interpretation acceptable? YES

```
=====
```


=====

sentence:

(John is a cold person)

skolemized indefinite logical form:

((COLD "John" "sk-anon1") (STATE "sk-anon1"))

skolemized definite logical form:

NIL

evoked-concepts:

"temperature0"

literal form:

(STATE "state0")

(COLD "John" "state0")

[John was physically cold]

Interpretation acceptable? NO

evoked-concepts:

"friendliness0"

literal form:

(STATE "state0")

(LITTLE "friendliness0" "state0")

(FRIENDLINESS "friendliness0")

[John was unfriendly]

Interpretation acceptable? YES

=====

3. ARGUMENT IS WAR

The DREP representation of the analogy underlying the ARGUMENT IS WAR systematic metaphor is shown in figure 3. Note that there are three associated analogies here: AN ARGUMENT IS A STRATEGIC OBJECT (a strategic object is an object of defence or attack in the military sense), CONVINCINGNESS IS STRENGTH / INTEGRITY (a convincing argument is a strong / sound argument), and CRITICISM IS ATTACK.

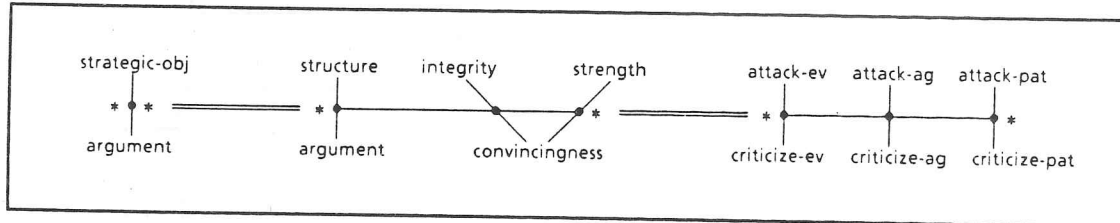


Figure 3: ARGUMENT IS WAR

Strictly speaking, the last of these ought to be redundant, as 'attack' could be defined as 'attempt to destroy a strategic object', in which case the other two analogies could be used to interpret an attack on an argument as an attempt to reduce the convincingness of the argument (i.e., a criticism of the argument). Unfortunately, MINT cannot yet handle constructions such as 'to attempt to' so the more direct third analogy is employed. This third analogy is, in effect, defining a polysemous sense for 'attack', linking it to the ARGUMENT IS WAR core analogy – this is exactly the way in which MINT could cache useful polysemous senses.

```
=====
sentence:
  (John attacked Bill's theory)
skolemized indefinite logical form:
  ((ATTACK "John" "sk-anon1" "sk-anon2") (EVENT "sk-anon2"))
skolemized definite logical form:
  ((THEORY "sk-anon1") (OF "sk-anon1" "Bill" THEORY))
-----
evoked-concepts:
  "theory0"

literal form:
  (EVENT "event0")
  (OF "theory0" "Bill" THEORY)
  (CRITICIZE "John" "theory0" "event0")

[John criticized Bill's theory]

Interpretation acceptable? YES
=====
```

```

=====
sentence:
  (John shot down Bill's argument)
skolemized indefinite logical form:
  ((SHOOT-DOWN "John" "sk-anon1" "sk-anon2") (EVENT "sk-anon2"))
skolemized definite logical form:
  ((ARGUMENT "sk-anon1") (OF "sk-anon1" "Bill" ARGUMENT))
-----
evoked-concepts:
  "conseq-state0" "convincingness0" "argument0"

literal form:
  (EVENT "event0")
  (OF "conseq-state0" "event0" CONSEQUENT-ST)
  (REDUCED-TO-NOTHING "convincingness0" "conseq-state0")
  (REDUCE-TO-NOTHING "John" "convincingness0" "event0")
  (CRITICIZE "John" "argument0" "event0")
  (OF "argument0" "Bill" ARGUMENT)
  (ARGUMENT "argument0")
  (OF "convincingness0" "argument0" CONVINCINGNESS)

```

[John criticized Bill's theory,
reducing its convincingness to nothing]

Interpretation acceptable? YES

```
=====
```

```

=====
sentence:
  (Bill's argument is strong)
skolemized indefinite logical form:
  ((STRONG "sk-anon1" "sk-anon2") (STATE "sk-anon2"))
skolemized definite logical form:
  ((ARGUMENT "sk-anon1") (OF "sk-anon1" "Bill" ARGUMENT))
-----
evoked-concepts:
  "convincingness0" "argument0"

literal form:
  (STATE "state0")
  (GREAT "convincingness0" "state0")
  (OF "argument0" "Bill" ARGUMENT)
  (ARGUMENT "argument0")
  (OF "convincingness0" "argument0" CONVINCINGNESS)

```

[Bill's argument is convincing]

Interpretation acceptable? YES

```
=====
```

=====

sentence:

(John's theory is flimsy)

skolemized indefinite logical form:

((FLIMSY "sk-anon1" "sk-anon2") (STATE "sk-anon2"))

skolemized definite logical form:

((THEORY "sk-anon1") (OF "sk-anon1" "John" THEORY))

evoked-concepts:

"convincingness0" "theory0"

literal form:

(STATE "state0")

(LITTLE "convincingness0" "state0")

(OF "theory0" "John" ARGUMENT)

(ARGUMENT "theory0")

(OF "convincingness0" "theory0" CONVINCINGNESS)

[John's theory is unconvincing]

Interpretation acceptable? YES

=====

4. INFECTING IS GIVING

The two associated d-links behind MINT's processing of INFECTING IS GIVING are shown in figure 4. A disease is seen as a physical object whose transfer is interpreted as infection and whose possession is interpreted as a state of being infected.

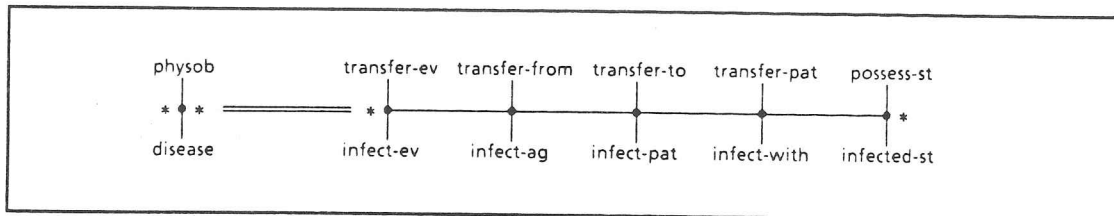


Figure 4: INFECTING IS GIVING

=====

sentence:

(John gave Mary a virus)

skolemized indefinite logical form:

((GIVE "John" "Mary" "sk-anon1" "sk-anon2") (VIRUS "sk-anon1")
(EVENT "sk-anon2"))

skolemized definite logical form:

NIL

evoked-concepts:

"conseq-state0"

literal form:

(VIRUS "virus0")

(EVENT "event0")

(OF "conseq-state0" "event0" CONSEQUENT-ST)

(INFECT "John" "Mary" "event0")

(INFECTED-WITH "virus0" "Mary" "conseq-state0")

[John infected Mary with a virus]

Interpretation acceptable? YES

=====

```
=====
sentence:
  (Mary caught a cold from John)
skolemized indefinite logical form:
  ((CATCH "Mary" "sk-anon1" "sk-anon2") (COLD "sk-anon1")
   (FROM "John" "sk-anon2") (EVENT "sk-anon2"))
skolemized definite logical form:
  NIL
```

```
-----
evoked-concepts:
  "conseq-state0"
```

```
literal form:
  (COLD "cold0")
  (EVENT "event0")
  (OF "conseq-state0" "event0" CONSEQUENT-ST)
  (INFECT "John" "Mary" "event0")
  (INFECTED-WITH "cold0" "Mary" "conseq-state0")
```

[John infected Mary with a cold]

Interpretation acceptable? YES

```
=====
sentence:
  (Mary has flu)
skolemized indefinite logical form:
  ((HAVE "Mary" "flu" "sk-anon1") (STATE "sk-anon1"))
skolemized definite logical form:
  NIL
```

```
-----
evoked-concepts:
  "anteced-event0"
```

```
literal form:
  (STATE "state0")
  (OF "anteced-event0" "state0" ANTECEDENT-EV)
  (INFECTED-WITH "flu" "Mary" "state0")
  (INFECT "=dummy=" "Mary" "anteced-event0")
```

[Mary is infected with flu]

Interpretation acceptable? YES

```
=====
sentence:
  (John is a carrier of AIDS)
skolemized indefinite logical form:
  ((CARRIER "John") (OF "John" "AIDS" CARRIER))
skolemized definite logical form:
  NIL
```

```
-----
evoked-concepts:
```

```
literal form:
  (CARRIER "John")
  (INFECTED-WITH "AIDS" "John" "=dummy=")
```

[John is infected with AIDS]

Interpretation acceptable? YES

5. TOUCHING IS GIVING

Figure 5 shows MINT's representation of TOUCHING IS GIVING. Here, any event of touching, such as a kiss, punch, smack, tap, is seen as an object which is 'given' to the patient of the event.

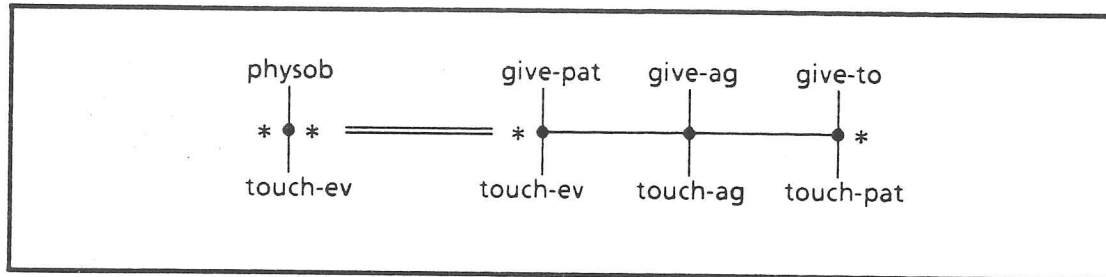


Figure 5: TOUCHING IS GIVING

```
=====
sentence:
  (John gave Mary a kiss)
skolemized indefinite logical form:
  ((GIVE "John" "Mary" "sk-anon1" "sk-anon2") (KISS "sk-anon1")
    (EVENT "sk-anon2"))
skolemized definite logical form:
  NIL
-----
evoked-concepts:

literal form:
  (EVENT "event0")
  (KISS "kiss0")
  (KISS "John" "Mary" "kiss0")
  (TOUCH "John" "Mary" "kiss0")

[John kissed Mary]

Interpretation acceptable? YES
=====
```



```
=====
sentence:
  (Mary sold John a kiss)
skolemized indefinite logical form:
  ((SELL "Mary" "John" "sk-anon1" "sk-anon2") (KISS "sk-anon1")
    (EVENT "sk-anon2"))
skolemized definite logical form:
  NIL
-----
```

evoked-concepts:

```
literal form:
  (EVENT "event0")
  (KISS "kiss0")
  (KISS "Mary" "John" "kiss0")
  (TOUCH "Mary" "John" "kiss0")
```

[Mary kissed John]

Interpretation acceptable? YES

```
=====
```

```
=====
sentence:
  (John gave Mary a smack)
skolemized indefinite logical form:
  ((GIVE "John" "Mary" "sk-anon1" "sk-anon2")
    (SMACK "sk-anon1") (EVENT "sk-anon2"))
skolemized definite logical form:
  NIL
-----
```

evoked-concepts:

```
literal form:
  (EVENT "event0")
  (SMACK "smack0")
  (SMACK "John" "Mary" "smack0")
  (TOUCH "John" "Mary" "smack0")
```

[John smacked Mary]

Interpretation acceptable? YES

```
=====
```

```
=====
sentence:
  (Mary took a smack from John)
skolemized indefinite logical form:
  ((TAKE "Mary" "sk-anon1" "sk-anon2") (SMACK "sk-anon1")
    (EVENT "sk-anon2") (FROM "John" "sk-anon2"))
skolemized definite logical form:
  NIL
-----
```

evoked-concepts:

```
literal form:
  (EVENT "event0")
  (SMACK "smack0")
  (SMACK "John" "Mary" "smack0")
  (TOUCH "John" "Mary" "smack0")
```

[John smacked Mary]

Interpretation acceptable? YES

```
=====
```

6. The conduit metaphor [Reddy 79]

This complex systematic metaphor is represented as a group of seven associated analogies corresponding to simpler systematic metaphors. Most of these analogies refer to the complex communication 'frame'³ which has slots for communicate-ev (the overall event of communicating), communicate-ag (the speaker or author), communicate-pat (the meaning which is communicated), communicate-to (the hearer or reader), message (the utterance or text), express-ev (the act of utterance or writing), and understand-ev (the act of comprehension of the meaning in the message).

The individual d-links represent the lower level systematic metaphors TO MEAN IS TO CONTAIN (where the message 'means' the meaning), TO EXPRESS IS TO PUT INTO (the communicator 'puts' his meaning into the message), TO UNDERSTAND IS TO EXTRACT (extract the meaning from the message), and COMMUNICATION IS MOVING (the meaning is moved from the speaker to the hearer in the message). Finally, there is an analogy describing the 'density' of meaning in a message as the 'fullness' of the message.⁴

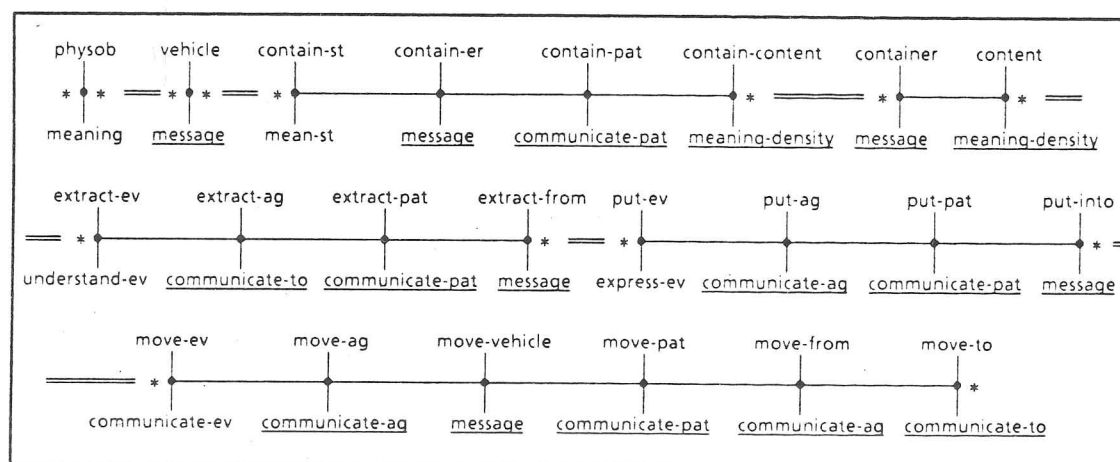


Figure 6: The conduit metaphor

Because of the complexity of the semantics used in these examples, there are two predicates which need some explanation:

MEANING-PART is used in preference to MEANING to emphasize that only a part of the meaning of a message is given. M. SAMPLE expresses the relation that a particular meaning is a 'sample' of some mass term, such as emotion (analogous, say to a sample of butter, or of gold).

³ See chapter 5 for an explanation of the frame interpretation of DREP.

⁴ see Appendix B for a greater range of examples showing how these metaphors are used.

=====

sentence:

(an idea)

skolemized indefinite logical form:

((IDEA "sk-anon1"))

skolemized definite logical form:

NIL

evoked-concepts:

literal form:

(IDEA "idea0")

[This just sets up a referent]

Interpretation acceptable? YES

=====

sentence:

(Bill put the idea into a letter)

skolemized indefinite logical form:

((PUT "Bill" "sk-anon1" "sk-anon2") (EVENT "sk-anon2")

(INTO "sk-anon3" "sk-anon2") (LETTER "sk-anon3"))

skolemized definite logical form:

((IDEA "sk-anon1"))

evoked-concepts:

literal form:

(EVENT "event0")

(LETTER "letter0")

(MESSAGE "letter0")

(OF "Bill" "letter0" AUTHOR)

(OF "idea0" "letter0" MEANING-PART)

(COMMUNICATE "Bill" "idea0" "=dummy=")

(EXPRESS-IN "Bill" "idea0" "letter0" "event0")

(EXPRESS "Bill" "idea0" "event0")

[Bill expressed (and communicated) the idea in a letter (a message).

Bill was the author of the letter]

Interpretation acceptable? YES

=====

=====

sentence:

(a poem)

skolemized indefinite logical form:

((POEM "sk-anon1"))

skolemized definite logical form:

NIL

evoked-concepts:

literal form:

(POEM "poem0")

[This just sets up a referent]

Interpretation acceptable? YES

=====

```

sentence:
  (The poem was full of emotion)
skolemized indefinite logical form:
  ((FULL "sk-anon1" "sk-anon2") (STATE "sk-anon2")
   (OF "emotion" "sk-anon2"))
skolemized definite logical form:
  ((POEM "sk-anon1"))
-----
evoked-concepts:
  "meaning-density0" "anteced-event0" "meaning-sample0"

literal form:
  (STATE "state0")
  (OF "anteced-event0" "state0" ANTECEDENT-EV)
  (MAXIMAL "meaning-density0" "state0")
  (OF "meaning-sample0" "emotion" M.SAMPLE)
  (MESSAGE "poem0")
  (OF "meaning-density0" "poem0" MEANING-DENSITY)
  (OF "meaning-sample0" "poem0" MEANING-PART)
  (EXPRESS-IN "=dummy=" "meaning-sample0" "poem0" "anteced-event0")
  (EXPRESS "=dummy=" "meaning-sample0" "anteced-event0")

```

[Emotion was expressed in the poem and
the 'meaning density' of the poem was maximal]

Interpretation acceptable? YES

=====

=====

```

sentence:
  (an essay)
skolemized indefinite logical form:
  ((ESSAY "sk-anon1"))
skolemized definite logical form:
  NIL
-----

```

evoked-concepts:

```

literal form:
  (ESSAY "essay0")

```

[This just sets up a referent]

Interpretation acceptable? YES

=====

```

sentence:
  (the essay was crammed with ideas)
skolemized indefinite logical form:
  ((CRAMMED "sk-anon1" "sk-anon2") (STATE "sk-anon2")
   (WITH "ideas" "sk-anon2"))
skolemized definite logical form:
  ((ESSAY "sk-anon1"))
-----
evoked-concepts:
  "meaning-density0" "anteced-event0" "meaning-sample0"

literal form:
  (STATE "state0")
  (OF "anteced-event0" "state0" ANTECEDENT-EV)
  (MAXIMAL "meaning-density0" "state0")
  (OF "meaning-sample0" "ideas" M.SAMPLE)
  (MESSAGE "essay0")
  (OF "meaning-density0" "essay0" MEANING-DENSITY)
  (OF "meaning-sample0" "essay0" MEANING-PART)
  (EXPRESS-IN "=dummy=" "meaning-sample0" "essay0" "anteced-event0")
  (EXPRESS "=dummy=" "meaning-sample0" "anteced-event0")

```

[Ideas were expressed in the essay and
the 'meaning density' of the essay was maximal]

Interpretation acceptable? YES

=====

=====

```

sentence:
  (Mary poured her sorrow into a letter)
skolemized indefinite logical form:
  ((POUR "Mary" "sk-anon1" "sk-anon2") (EVENT "sk-anon2")
   (INTO "sk-anon3" "sk-anon2") (LETTER "sk-anon3"))
skolemized definite logical form:
  ((OF "sk-anon1" "Mary" SORROW))
-----

```

```

evoked-concepts:
  "sorrow0"

literal form:
  (EVENT "event0")
  (OF "sorrow0" "Mary" SORROW)
  (LETTER "letter0")
  (MESSAGE "letter0")
  (OF "Mary" "letter0" AUTHOR)
  (OF "sorrow0" "letter0" MEANING-PART)
  (EXPRESS-IN "Mary" "sorrow0" "letter0" "event0")
  (EXPRESS "Mary" "sorrow0" "event0")
  (COMMUNICATE "Mary" "sorrow0" "=dummy=")

```

[Mary expressed (and communicated) her sorrow in a letter]

Interpretation acceptable? YES

=====

```
=====
sentence:
  (John gave Bill an idea)
skolemized indefinite logical form:
  ((GIVE "John" "Bill" "sk-anon1" "sk-anon2")
   (EVENT "sk-anon2") (IDEA "sk-anon1"))
skolemized definite logical form:
  NIL
-----
```

```
evoked-concepts:
  "conseq-state0"
```

```
literal form:
  (IDEA "idea0")
  (EVENT "event0")
  (OF "conseq-state0" "event0" CONSEQUENT-ST)
  (EXPRESS "John" "idea0" "=dummy=")
  (COMMUNICATE-TO "John" "Bill" "event0")
  (COMMUNICATE "John" "idea0" "event0")
```

[John communicated an idea to Bill]

Interpretation acceptable? YES

```
=====
```

```
=====
sentence:
  (Bill got his argument across to John)
skolemized indefinite logical form:
  ((GET "Bill" "sk-anon1" "sk-anon2") (EVENT "sk-anon2")
   (ACROSS "=dummy=" "sk-anon2") (TO "John" "sk-anon2"))
skolemized definite logical form:
  ((OF "sk-anon1" "Bill" ARGUMENT))
-----
```

```
evoked-concepts:
  "argument0"
```

```
literal form:
  (EVENT "event0")
  (OF "argument0" "Bill" ARGUMENT)
  (EXPRESS "Bill" "argument0" "=dummy=")
  (COMMUNICATE "Bill" "argument0" "event0")
  (COMMUNICATE-TO "Bill" "John" "event0")
```

[John communicated his argument to Bill]

Interpretation acceptable? YES

```
=====
```

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